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MAN'S IMITATION OF NATURE IN PURIFICATION OF WATER.

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As engineers, you are asked to suggest a means of supplying a municipality with a suitable water supply. This means to the engineer a potable water and one which at the same time is adaptable to mechanical uses, for the production of steam and for domestic purposes.

In looking over the immediate vicinity of the locality to be supplied, it is seldom that a supply which is satisfactory in quantity and quality is available. If the water is exceptionally pure the quantity is sure to be limited, and if in considerable quantity it is apt to be so far removed as to make it impracticable to introduce the supply when the question of expense is considered. When it is necessary to depend upon ponds, lakes or rivers the probabilities are that the supply is already receiving contaminations or the watershed is liable to invasion from human habitation and will at some future time become liable to contamination.

The question then arises as to how far we are justified in recommending a supply which is polluted or liable to pollution, and at the same time we may ask whether there is really any such a thing as a pure water supply obtainable.

Of this fact, that there are supplies which are naturally pure is shown by the analysis of the water supplies of many municipalities. These waters taken from their original source are delivered to the consumer without artificial interference of any kind, and are yet satisfactory in quality and quantity.

There are waters therefore which are purified by nature, for in their original state as supplied by the natural rain they are contaminated by the air through which they pass and by the surface contaminations which are gathered to the water from the surface of the earth where the rain has fallen. Yet this same water comes to us from subterranean passages clear and pure, bacteriologically and chemically. What was once a muddy, highly colored water loaded with organic and mineral matters in suspension has been deprived of those ingredients and the water comes to us white in color, palatable to the taste and free from excess of organic matter though highly charged with mineral matter in solution.

It is desirable that we become perfectly familiar with nature's methods in effecting these conditions, for we are now daily called upon to produce these changes artificially, rapidly and upon a large scale. In so doing there has been no device presented or method or process which is not an imitation of nature, unless it be the process of boiling the supply and as this water is devoid of taste from loss of aereation it cannot be called a potable water.

The purest waters obtainable in nature are derived from so-called natural springs or from artesan or driven wells, which are natural springs tapped by man.

Our natural inquiry is at once directed to the conditions to which this water is subjected—this water which was once impure and now comes from the depths of the earth free from all contaminations. We are at once informed by those who have given this matter much thought and investigation that this water has been percolated or filtered through innumerable layers, of varying densities of earth and that the many particles of organic matter held in supension have become caught in the meshes or interstices of the media through which it is passed leaving the water free from suspended matters. Natural springs uncontaminated by matters received from the surface flow, and artesian and driven wells taking water from below an inpervious strata should be bacteriologically pure to the extent of less than fifty organisms per cubic centimetre, and in

many cases it is possible that even such numbers may be derived from pump packings or from effluent pipes. The writer has examined several waters which were practically sterile taken from these sources. When a contaminated river water, or a muddy river or lake water is the only source available for a city supply, the engineer avails himself of nature's methods and endeavors to imitate by constructing sand beds of fine sand, which we are told, as the results of actual experience in Europe and as the result of long and careful experimentation at Lawrence, should be of a certain depth, and the sand of a certain degree of fineness and through which the water may be allowed to pass. But in our attempts to supply the large quantity of water required for a city supply we are tempted to permit the water to pass through the filter in such large quantities, or rather at such a rapid rate, that the effluent waste is not as clear and pure as desired and does not resemble nature's product.

When we inquire from our experts at the experiment station the reason for this we are informed that the water which has been filtered by nature has been drawn from a large area and that the rate of filtration has been extremely slow, and that in many instances it has passed to great depths. This latter requisite however is not essential as is shown by examination of a filter bed, the most efficient filtration being effected by the first few inches of sand on the surface, the substrata or coarser sand serving merely as a supporting mass or foundation for the finer filtering media.

Until recently we were also advised that the mass of organic matter which is caught on the surface of the filter bed, forming a thin scum or slimy stratum, served solely as a filtering media and without that layer successful filtration could not be accomplished. It has now been determined however that after filtration has been commenced and the layer once formed that the scum may be removed, and if the superstrata of sand is not disturbed that quite effectual filtration, though not complete, may be accomplished. We were told that if a fracture or lack of continuity of this slimy surface occurred that the impure water would find its way through without purification. This still holds true, for in this case there is a break or channel passing through the upper layer of sand as well as through the slimy layer.

Equipped with this data the engineer attempts to judge of the depth of sand necessary for a water of average impurity. He esti-

mates the rate of filtration possible through this material and then determines the area of surface which will be required for filtering the enormous amount of water required for a given municipality. This naturally leads to the consideration of cost, for unless the large acreage required be available at some point removed from the city where land is of slight expense, the cost for the land becomes a serious obstacle. Even after the land becomes available the cost of a sand of a requisite degree of fineness and sharpness must be considered since it must usually be obtained from a distance and the transportation adds materially to the cost. If, as is the case of Atlanta and other cities, where the water must be raised to a considerable height in order to reach the filter bed, the cost is proportionally increased. The city is fortunate therefore which can avail itself of the natural fall of the supply to flood the beds without pumping. This is demonstrated in the filter plant which is in use at Denver. Here the water flows from the mountains directly into the filters which are in this case semi-mechanical filters, that is, are tanks of sand which are cleaned by agitation of the sand by means of revolving forks and return flow, but in which no alum is used.

Another means which nature has provided and which serves in many cases, as in the supplementary plant in Denver, is the natural formation of filter galleries and which is imitated by man in the use of natural soil found on the banks or beneath the beds of streams where the natural earth formation is of the proper porosity. This form of filtration is, however, usually so rapid that little more than the gross suspended matter is removed, and as is the case with all filtration, the less the amount of organic or suspended matter present in the water, the more difficult is perfect filtration. Reversely, the greater amount of suspended matter, the more successful the filtration. This naturally occurs as the result of the organic matter becoming caught in the interstices of the filtering media, and as we previously were led to believe the organic matter present produces more quickly an effective filtering scum or surface layer upon the supporting sand.

In examining the purest waters derived from artesian wells it has been found that they contained large quantities of mineral salts. These we are told have been taken up from the earth and from the soluble elements through which the water has percolated. This advances the suggestion that nature has possibly utilized these salts in

a measure to assist in the purification, and leads us to consider the results if we should add to our unpurified water, salts of a similiar character, or other materials, which would produce an effect of some kind upon the suspended matters in our impure waters. Therefore alum, iron and other chemicals have been suggested from time to time, but alum, from its availability and from its more successful action upon suspended organic matters in water, has been adopted at the present time as being the most desirable coagulant or precipitant. We have therefore introduced to our attention the process of mechanical filtration, that is, the utilization of a precipitant in addition to the use of mechanical devises which aid in the cleansing of the filtering media which constitutes the bed, and to which system the name of American filtration has been applied.

This method we have placed before us by the various patented systems which have the same common principle of a coagulant and agitation of a filter bed. We are familiar with these systems first known as the Hyatt filter, and now known under the names of the Morison-Jewell filter, the New York filter, the Warren filter, the Western and the National, and which have now been amalgamated under the firm name of the New York Filter Company.

These practically differ from each other only in the method of applying the precipitant and in the use of certain accurate mechanical devices for introducing the precipitant and latterly in the treatment of the applied water before being introduced into the filter proper. One other difference has up to the present time existed, and that has been a great obstacle to the introduction of mechanical filtration, and that is the litigation which has attended the installation of these plants.

As we are all aware, much valuable time, money and loss of valuable contracts have occurred as the result of the many injunctions and threats of the New York Filter Company against the Morison-Jewell Company; but after the installation of the Niagara plant and the Lorraine plant by the Morison-Jewell Company, and the many injunctions against them in favor of the New York company, the matter has now come to an end, and it is safe to say that under new administration it may be possible for either or both companies to introduce their processes to a city without being obstructed on the grounds of suits for infringements.

The city of Providence having appropriated the sum of $180,000

for a filtration plant of 15,000,000 gallons capacity, withheld the signing of the contract at the last moment owing to fears of litigation. The city of Albany was strongly influenced in contracting for a natural filtration plant, to avoid litigation.

As has been stated, the chemicals used in this method are similarly used by each company, but they have until recently been applied in entirely different ways. The method adopted by the New York Filter Company and as is in use at the filtration plant at Atlanta, Georgia, and other plants, is to place an indefinite bulk of crude alum in a receiver through which a small by-pass of water may flow, and which again enters the applied water before reaching the filter. It requires but little reflection to satisfy oneself that the water passing about the large bulk of alum soon after the first charge in the receiver must necessarily be a saturated solution and may be supplying more grains per gallon of water than is necessary to produce the change or precipitation of the organic matter present, and thus make it possible to have a quantity of alum in the mains. Likewise, when the alum in the receiver has been reduced to a minimum, from its constant contact with the passing water, the remaining amount of alum cannot give up the necessary amount of grains per gallon to successfully purify the water. This method of applying the precipitant is therefore unreliable. The use of this method of filtration is not in all cases for the purpose of removing suspended matters which are visible to the eye and which, while harmless, are yet unsightly or odorous. It may be used in comparatively clear waters which have a known contamination from excreta from man. Into the supply pipes no water should pass without being treated with the proper amount of precipitant, for as soon as the alum is reduced to below the normal requirement, the water passing through becomes a possible source of danger. To the mind of the engineer or ordinary mechanic it would seem absurd that this clumsy method should continue in practice or be presented to a municipality for use. The suggestion would at once present itself: why not apply the desired amount in strength and quantity in proportion to the amount of organic matter present and in proportion to the amount of water passing through the filter, as we would naturally do when we desire any other exact chemical or mechanical mixture?

The Morison-Jewell Filter Company as with other companies which have been shown to be infringers upon the original method,

adopted appliances which would accomplish this. A solution of a standard strength of alum was mixed, the standard depending upon the amount of organic matter present and determined by experiment before filtration. This standard solution is then ejected into the applied water in quantity proportioned to the amount of water passing through the mains. This latter application is brought about by different devices by the different companies, and any preference would exist therefore for the best mechanical device which is used for injecting or mixing the applied solution.

But in the use of this form of coagulant we improve upon nature inasmuch as the amount of alum applied is in proportion to the demand and *no other salts* are added. In nature the amounts found are in excess of the need. One of the objections which has been raised to the use of the mechanical filtration is the alleged possibility of a dangerous quantity of alum finding its way into the filters and being a cause of injury to the consumers. As a matter of fact during the experiments conducted at Providence in the process of mechanical filtration, there appeared less alum in the filtrate than in the applied water before it was treated, and in the experiments made at Lorraine, Louisville, Cincinnati and at Pittsburg, Pa., the same results hold true. No objection has yet been raised to the use of artesian and driven well supplies, although carrying large quantities of mineral matter. I have never heard of, nor am I able to obtain any evidence that the use of water filtered in this way has ever given rise to any disturbance of the alimentary tract, the portion of the human economy which would be the first involved if injury was to result. No reports are obtainable from Atlanta or other cities using alum as a precipitant, although by the manner in which the alum is applied there must at times be an excess of the applied chemical.

To ascertain the actual practical conditions which may result from a use of alum in this way the writer recently made inquiry of the health officers in cities having supplies of all the plants treated by the mechanical process, for the purpose of ascertaining if sickness of any kind had occurred from the continued use of alum as a precipitant. It was found that a great many of the cities were practically using the sand bed filtration with the rapid rate and the use of reversal current in washing, and the aid of iron rakes, but did not make use of alum, either because the effluent was suffi-

ciently clear or because there was no suspicion of sewage contamination, or in some cases where there was known pollution, for the sake of economy, the water companies were satisfied with simple clarification, and did not care whether there was a bacterial efficiency or not.

Of over one hundred cities which had mechanical plants, fifty-seven made reply. Of these only forty-five were filtering the water. Of these only forty found it necessary to use alum. Of these, seven used the alum intermittently while the rivers ran turbid, and thirty-three were using alum continuously. The amounts varied from one-tenth of a grain per gallon to seven grains per gallon. In three or four alum had been found in the filtrate. In not a single instance had any illness or symptons of intestinal disturbance been heard of in those using alum.

It is natural to raise this alarm about the addition of a chemical to the water, although wool washings, acids and bleaching chemicals may be in the supply continuously yet no complaint is made, but the addition of alum produces the alarm.

If any injury were to result; if any substantial objection could be raised, it would be made by the producers of steam as the result of incrustation of boilers, but all evidence obtainable from cities using such water, and from boiler insurance companies constantly making inspections, does not reveal any objectionable conditions.

Man, while using the same methods as nature, yet can, by the perfect control of the process in mechanical filtration, be enabled to filter larger quantities in a shorter space of time. The same is true when compared with the cruder method of sand bed filtration. By the use of sand filtration, a flow of 2,000,000 to 3,000,000 gallons per acre is possible, while with a properly adjusted mechanical filtration plant it is possible to reach as high as 125,000,000 gallons per acre per 24 hours.

Mechanical filtration has also an advantage possessed by nature which is not obtained by the sand filtration, namely, the power to continue the process during severe weather. If, however, it is necessary to use the sand bed filtration and to cover the beds, it necessitates an expenditure which makes the original cost too expensive.

From a bacteriological standpoint, one process is as perfect as the other. The mechanical filtration has the advantage however of being

quickly cleansed, and by mechanical labor instead of the intervention of human labor with its attendant slowness, danger of contamination from dirty shoes in walking over the bare beds, and also the possibility of seams or cracks forming in the surface of the bed, which can be corrected only by re-dressing the surface and which requires much time.

We are, as sanitary engineers prone to condemn the use of water from the ordinary dug well if it is possible to obtain a general public supply free from contamination. Our condemnation of the ordinary farm or house well is as natural as it is to condemn an untrapped sink, and both frequently without reason. It must not be forgotton that a large part of the population of this earth are obliged to depend upon water from dug wells as their only source of water supply for all purposes, and that the people using these wells are still alive and will probably continue so with the continued use of these wells. While it is good judgment and a safe one to condemn a well which is located in a populous district, yet we should be ready to give our reasons therefor. If a cesspool or a vault or a drain is located near a well there is sufficient suspicion, without examination of the water, that it may at any moment be contaminated. Yet no contamination exists in the majority of cases. If we will recall the conditions of the substrata of earth in making excavations in and about abandoned cesspools and privy vaults, we will recall that the discoloration of the earth does not extend beyond a few inches. We will remember that if the night soil man does not remove the entire contents of the cesspool, that he will return again, and that soon, since the cesspool is rapidly refilled owing to the accumulation of an impervious covering which has accumulated on the bottom of the cesspool. This is however, merely visual observation. Repeated experiments have shown that nature in this manner removes the contaminations which are found in the cesspool wastes and allows merely filtered water free from bacterial contaminations to pass through. This is demonstrated by the experiments conducted at Lawrence and at the various sewage filtration plants. The writer has observed as the result of filtration of sewage at the plant located at Pawtucket, R. I., that a sewage which contains 500,000 to 1,000,000 organisms to the cubic centimetre, shows in the effluent only 500 organisms, and it is the purpose of the plant always to avoid the accumulation of the sludge upon the surface which in a short

time so clogs the filter as to bring the percolation to a standstill, thus allowing, of course, surface filtration as occurs in nature. Should the filtration go on to the point of a slimy covering, the number of organisms in the effluent would materially decrease.

This same rule holds true in regard to the question upon which we are sometimes called to decide in reference to the dangerous proximity of a grave yard to a well or a proposed river supply. The writer has never seen at any exhumation the contamination of the soil beyond a few inches from the containing case and with the same conditions present as in a cesspool where the liquid contents are in greater quantity, hence the possibility of contamination from the remains buried in a cemetery are very remote. I am fully aware of opinions to the contrary, and while the idea may be repulsive, yet we should, as advisors of the public, give expression to our scientific judgment and not to our sentiment.

As the result of the biological experiments of Koch, Kitasato, Proschauer and Loeser, it has been demonstrated that not only are the organisms of contagious diseases destroyed in a short time in the presence of the toxines formed in the cadaver by the organisms of decomposition, but that the contamination of the soil extends to but a few inches from the retaining case or from the carcasses of animals. This was determined by examination of soil and waters in which animals had been buried, and also by examination of subsoil waters found in wells in cemeteries. It was always found that such waters were as good as any waters from wells in the same vicinity outside of the cemeteries. Of course when a cesspool or a grave has for its floor the surface of a rock or a hardpan over which is constantly flowing a subsoil river, this river may be readily contaminated and the contamination be carried to a neighboring supply. The greatest danger from the proximity of cesspools and wells is the liability of a break occurring at any time in the subsoil strata whereby a direct flow of the cesspool contents directly into the well is made possible.

In looking back in our text books not so many years ago, we find the statements that water running over a certain distance, usually cited as from seven to twelve miles, will purify itself, or rather become purified. It has also been stated, and generally believed, that the more agitation the water underwent, the more waterfalls over which the water ran, the sooner would the water be purified. But

at the present day, with our advanced knowledge and continued experimentation, we find, as we did with the all destroying theory of sewer gas, that we were preaching from a false prophet.

That the first statement is incorrect is shown, not alone by the continued examination, chemically and bacteriologically, of streams which have a known source and quantity of pollution, but is mournfully demonstrated by the epidemics which occur from time to time where a town affected by typhoid fever or cholera gives rise to an epidemic of the same kind and situated an indefinite number of miles below on the same river. Those who have watched the accumulation of fœcal matters at the mouth of a sewer, and in the winter time have seen these hardened masses discharged into a river and have seen them appear at distances further down the stream, know of the possibilities of contamination carried long distances.

While waterfalls and rapids serve to break up masses of this kind, as well as of organic matters of other kinds, and while it was supposed that the exposure to the sunlight and air brought about by this agitation would facilitate oxidization, we are now lead to believe that if this same water could pass along slowly, with occasional interruptions or impounding, that the water would be purified in a more rapid manner.

In 1894, Dr. Wyatt Johnson, bacteriologist of the Provincial Board of Health of Quebec, reported at a meeting of the American Public Health Association the results of the bacteriological investigations made with reference to the waters of the Ottawa and St. Lawrence Rivers in regard to sedimentation. He calls attention to the fact that local conditions influence sedimentation owing to variation in temperatures.

Sedimentation is naturally more marked in waters carrying a large amount of suspended matter than in clear waters and is greater when the sediment is dense than when light and flocculent. The conditions also are influenced by the keeping capacity of the water when stored.

At the foot of an aqueduct is a basin or pond about 15 feet deep, called the settling basin, and containing 23,000,000 gallons of water. The daily consumption in Montreal is 18,000,000 gallons, and double that amount is used for turbines, hence the chance for sedimentation is very unfavorable.

August 7 and September 12, at the basin there were 168 bac-

teriological colonies per cubic centimetre, while at the intake there were 84 per cubic centimetre.

The lower reservoir has a capacity of 35,000,000 gallons and 20 to 25 per cent of this is replaced by fresh water. The conditions are more favorable for sedimentation than at the settling basin.

The results of bacteriological examinations made monthly for a period of eleven months showed an average of 178 colonies to the cubic centimetre in the water at the basin and an average of 72 at the reservoir, showing a reduction or disappearance of 42 per cent of the organisms present in the supply. It was found that the bacteria varied inversely with the rapidity of the current.

In examination of the waters of the Ottawa river he found that water taken from a small lake in the course of the river and a few miles above Ottawa contained 20 bacteriological colonies. In the river between the lake and the city this number rose to 157. Some miles below Ottawa the number rose to 1,530 on one occasion, and on another to 520 as a result of the pollution of the river from the sewage of the city, notwithstanding the large volume of water in the river, (60,000 cubic feet per second) the volume of the sewage, however, not being estimated. This increase of bacteria gradually subsided, and at *fifty* miles below Ottawa the number had fallen to 48.

In the endeavor to modify the process of mechanical filtration in order to avoid infringement upon the patents of the New York Filter Company, the other companies introduced into their processes the holding of the water for a certain period after the addition of the coagulant, and before it enters the filter. This was accomplished by the introduction of weirs either perpendicular or horizontal, causing the passing of the water to be retarded sufficiently to permit of a certain amount of sedimentation. However, injunctions were repeatedly granted, restraining the use of the precipitant in this manner, it being ruled by the courts that inasmuch as the same amount of water was continuously supplied, that there was no cessation of the movement of the water, and hence the flow was continuous and was a part of the patented process.

In the introduction of the preliminary sedimentation tanks in the experiments carried out at Louisville, it was discovered that the precipitation which occurred was very material in amount, and, in fact, was absolutely essential for the practical use of the filter, owing to the amount of suspended mineral matter in the river water.

In the form of detention or precipitation tank used by the Morrison-Jewell Filter Company, the sediment tank was placed below the sand bed tank, and was round. The precipitation was at times accompanied by the formation of masses or balls of the coagulant and organic matter. These flocculent masses appeared to be the result of the rotary motion acquired by the water in the precipitation chamber. Professor Mason, of the Troy Polytechnic, calls attention to this peculiar action, and claims that the rotary motion of the water with the chemical ingredients produces a more rapid and complete precipitation than when the fluid is moving in a direct line or when at rest.

Whether this action takes place as the result of the molecules of the chemical being brought into more rapid contact with the other ingredients or whether attrition of the particles causes agglutination from the centrifugal action is not explained.

The evident impracticability of introducing the water of the western rivers directly upon a natural sand bed for filtration necessitates a preliminary sedimentation for a long period. Hours will not suffice, the time must run on into days.

The experiments now being carried on by the Louisville Water Company, and under the direction of Mr. George W. Fuller, formerly of the Lawrence Experiment Station, are for the determination of the most expeditious method of attaining the best results in this way: A sedimentation is allowed for varying periods, the time at present being five days. The decanted or siphoned water is then passed to the surface of the sand beds for filtration. The resulting filtrate, however, appears with a slight milky opacity, due to the microscopic particles of mineral matter, which are so small as to be able to pass through the interstices of a filtering media which will retain *bacteria* to the extent of over 99 per cent. The size of these particles have been estimated by Mr. Fuller to be at least one-sixth the size of the average water bacteria. This fine material can be removed by the addition of alumina before filtration, but as it it the purpose of the experiments to avoid the expense attending the use of this chemical, it is Mr. Fuller's endeavor to dispose of this by other means if possible.

In this connection it is interesting to note that by this preliminary sedimentation of five days, from sixty to eighty per cent of the bacteria are removed. This would support the theory that the re-

moval of the bacteria was a mechanical process, the organisms adhering to the organic matter for their support or food, and the organic matter being carried down by the precipitation of the mineral matters. Also, the use of alumina does not bring about a chemical change upon the bacteria, but uniting with the organic matter and the carbonates in the water forms a flocculent mass which from its weight carries the suspended matters to the bottom. This is verified by the laboratory experiments where it is shown that the bacteria continue to thrive in a strong solution of alum.

An interesting result in sedimentation is to be found in the operation of the plant used by a small town located across the river from Cincinnati. Provision has been made for storage in two reservoirs of a three million gallon supply. The water is drawn from either of these two reservoirs into a third which is the delivery reservoir. In this way the water may be held for a longer or shorter period until it is deemed sufficiently clarified to draw off, this varying with the turbidity of the waters in the river. It is the custom to allow for precipitation for a period of thirty days.

The result is quite satisfactory, disposing of a large percentage of the suspended mineral matter. Naturally the cost of such a plant is greatly enhanced owing to the large area of storage necessary.

As an illustration of the variance of waters seemingly having the same origin and similar composition, is shown in a comparison of the waters treated at Cincinnati and those treated at the experiment station located at Pittsburg. At the latter place the waters have the same appearance as at Cincinnati, yet upon passing the water through the same depth of sand as without any chemical treatment, the water appears clear and sparkling and free from any milkiness as that passed through the two mechanical filters or through the Worms filter, all of which are being tested at the same plant. If the rate exceed three million gallons per acre in the twenty-four hours the milkiness will commence.

When the report of the Louisville experiments, which are being prepared for publication by Mr. Fuller, are issued and the report of the Cincinnati work is completed, and the results of the experiments at Pittsburg, which are practically completed, become available we shall have much valuable data upon which to base our recommendations for either form of filtration, the sand bed or the American system.

DISCUSSION.

THE PRESIDENT. Mr. Clark, will you say something upon the subjects suggested by Dr. Swarts' paper?

MR. CLARK. The larger part of the paper is devoted to the subject of mechanical filtration, which I confess I know very little about, having had but little experience in that line. Dr. Swarts spoke about sedimentation being necessary before filtration by natural sand filters, and I understand that they intend to have that at Louisville, where they are expecting to install mechanical filters. We have with us Mr. Weston, who was associated with Mr. Fuller during most of the Louisville experiments, and I think he ought to be able to tell us something about mechanical filters, and the plant they propose to install at Louisville.

MR. ROBERT S. WESTON. I am not prepared to say very much on the general subject of mechanical filters. Mr. Fuller's report will be published in about twenty days, and you can then get the whole matter at first hand without having it filtered through me. I would like to say some few things, however, about the removal of bacteria by sedimentation and the removal of suspended matter by sedimentation.

Perhaps you know, and perhaps you do not know, that linked with the sanitary problem in Louisville, of removing the bacteria, which average about 40,000 per cubic centimetre, is the problem of removing about 46 tons of suspended matter on the average, and as high as 175 tons, I think per day, for a supply of 20,000,000 gallons.

To show what sedimentation will do, I will call your attention to quite an interesting plant in the city of New Albany, Indiana, directly opposite Louisville. On what are called nobs or bluffs back of the city they have installed three reservoirs, on three separate hills, so that the water will flow from the highest reservoir into the intermediate one, and from the intermediate one into the lowest one, and from this lowest reservoir to the town. That water, which is of course the same in character as is supplied to the city of Louisville, at present flows through these reservoirs in about one month, and becomes a very satisfactory water at the end. It may be especially judged so from the fact that they have very little typhoid fever in New Albany, less than thirty cases, I think, per 100,000 per annum, and although they receive the sewage of the city of Louis-

ville in their supply, while Louisville, which takes its supply above itself and above New Albany, has from seventy to seventy-eight cases per annum per 100,000. This shows the efficiency of a settling reservoir as a sanitary measure.

The filter plant proper in Louisville has not been decided upon, I think I may say, without any danger of being contradicted, the principal part of the construction work there being the construction of the necessary clear water basin and of the pumping machinery and standpipe necessary to restore the loss of head which will take place if filters are installed. The plant they have designed will be quite extensive—this has been given in the daily papers of Louisville—and it is to have a capacity or 25,000,000 gallons per day. The water is now stored in a 100,000,000 gallon reservoir, which is divided through the middle by a partition wall. It is proposed to take the water from this 100,000,000 gallon reservoir after it has settled there about four days, and pass it through filters of some type, probably the American type, though I have no authority to say they will use that type to the exclusion of any other. But Mr. Hermany says he is satisfied that some filter will have to be established there which contains devices for cleaning the sand, other than those in use on the European type of filter. You can readily understand that, when you consider the immense weight of suspended matter in the river water.

The bids were opened for this clear water basin on September 1st. The idea is to take the water from the present reservoir and run it through the filters, and from those into the clear water basin which is to be located under the filters, and then the water will be repumped into the standpipe.

The extremely small size of the particles of suspended matter in the waters of our western states has been often spoken of, but I think those of you who have never seen the western rivers have little conception of the extreme fineness of that suspended matter. The Merrimac river for instance, when it gets on a rampage, brings down a good deal of suspended matter, but it is a crystaline suspended matter, and after standing some time the water will settle out comparatively clear. I have kept samples of water standing in the laboratory at Louisville from four to five months without becoming clear. It has been stated by several eminent authorities that these particles of clay stand midway between a

simple suspension and a solution. That is, the clay is so expanded, we may say, so swelled, a good deal as starch is swelled when it is diluted or soaked in water, that it is almost impossible for it to settle out of solution. But, whatever the theory of the matter may be, the fact remains that the clay in that water is very hard to precipitate. To do it the filter companies which have experimented there have used sulphate of aluminum, which, reacting with the lime in the water, produces the nitrate of aluminum, and by its sedimenting and developing and coagulating, and by other actions which may be induced in the suspended matter, it causes a clarification of the water, and also forms a film on the surface of the sand and around the grains of sand, which makes the filter act as an extremely fine strainer for the suspended matter and for the bacteria.

A competitive trial of the different systems of filtration, as you will see in Mr. Fuller's report, was conducted at Louisville from the 1st of September, 1895, until the 1st of August, 1896, with varying degrees of success. A great many problems were met for the first time, and there were partial successes and partial failures, but a great deal was learned; and then the summer of 1896 and the time along until the middle of the winter was spent in writing up the report of those experiments. The following spring, at the instigation and advice, I think, of Professor Mark, the Superintendent of Schools at Louisville, and Professors Brownell and Palmer of the Manual Training School at Louisville, a plant was set up in the laboratory for the preparation of the coagulant by electrical means rather than by chemical means. Of course, when the sulphate of aluminum was put into the water it reacts with the dissolved alkali, the lime, in the water, and nitrate of aluminum is produced. Now, this same nitrate can be produced if you put two plates of the metal aluminum, or if you put two plates of iron in the water and pass an electrical current through the plates, it has exactly the same effect, and equally good results can be obtained from it. The difference in practicability is one of dollars and cents; and to what extent you will see from Mr. Fuller's report when it comes out.

Those experiments continued until the next summer, the 1st of August, 1897, and then the rest of the time was spent in gathering together all the data which had been obtained by those experiments.

All I can say about the Louisville work, all I am allowed to say as a subordinate, is this: That sufficient data have been gathered together so that an engineer can go to work and design a plant for the city of Louisville which will filter the water of the Ohio River in a sufficiently economical manner to be practicable. But if Mr. Hermany, the Chief Engineer of the Louisville Water Company, had gone to work and designed a filter plant with the data that the filter companies were ready to furnish him in 1895, the plant would have been a miserable failure, on account of being inadequate to handle the water at times of greater supply.

MR. WILLIAM H. THOMAS. As I understand it, a sand filter to be effective must have the film formation first. I should like to ask Dr. Swarts if that is correct?

DR. SWARTS. The idea used to be that the scum formation was absolutely essential, and that that was the filtering medium. If the scum were removed a certain amount of filtration would go on, but it would not give as perfect a result as with the scum.

MR. THOMAS. If that is so, what is the need of the graduation of the sand bed?

DR. SWARTS. In mechanical filters the sand grains are all the same calibre, and they are mixed up so that what is at the bottom may be at the top; whereas in sand bed filters, as I understand it, the larger stones are placed at the bottom, the next layer being smaller, and the smallest being at the top, and that acts as the filtering medium.

MR. WESTON. There is no graduation of the sand in a sand bed filter; there is simply a graduation of the bed under the sand.

MR. CLARK. I do not think the scum on the surface is always necessary. It is a very effective part of a filter bed, but if you run a filter long enough you will find that the organic matter from the water is left not only upon the surface, but it passes down through to a certain depth and coats the sand grains. Of course the amount on the sand grains diminishes as you go down, but still there is enough of the coating left so you have it a number of inches deep. So when the surface scum is removed from the top the filter is still efficient.

MR. CODD. I would like to ask to what depth this scum is found on the sand?

MR. CLARK. That is pretty hard to say. It diminishes as you

go down, of course, and it dimishes very rapidly. But after a filter has been in use three or four years, with the same sand in it, you will find sand grains down to a depth of two or three feet with an appreciable coating. And after a certain amount gathers there it seems to stay about the same without increasing or decreasing. Of course if the filter is overworked, too much water passing through it, it will clog to a considerable depth, and the sand will have to be removed to a considerable depth. We have filters in use at Lawrence which have been filtering water for five years, and there are at least 44 inches of the original sand still in those filters, although the under grains are coated to a considerable depth.

THE OCCURRENCE OF CRISTATELLA IN THE STORAGE RESERVOIR AT HENDERSON, N. C.

BY ROBERT S. WESTON, CHEMIST AND BACTERIOLOGIST,
WEST SUPERIOR, WISCONSIN.

[*Read Sept. 15, 1898.*]

On the 14th of last July, the writer was called in by the Henderson Water Company, Henderson, N. C., to investigate the cause of, and prescribe a remedy for the bad odor which prevailed in the water supply during the summer months.

A short investigation was therefore conducted with the following results: In a few words, the water supply of Henderson is from impounded, spring fed brooks, which latter drain a sparsely settled watershed. The population of the watershed is 509.

Most of the population is housed in the corporation dwellings belonging to the Henderson cotton mill, 6,600 feet distant from the head of the reservoir. The rest of the population consists of farmers and the residents of Andrews avenue, who live in the vicinity of the standpipe.

The sanitary census of the watershed has been prepared as follows:

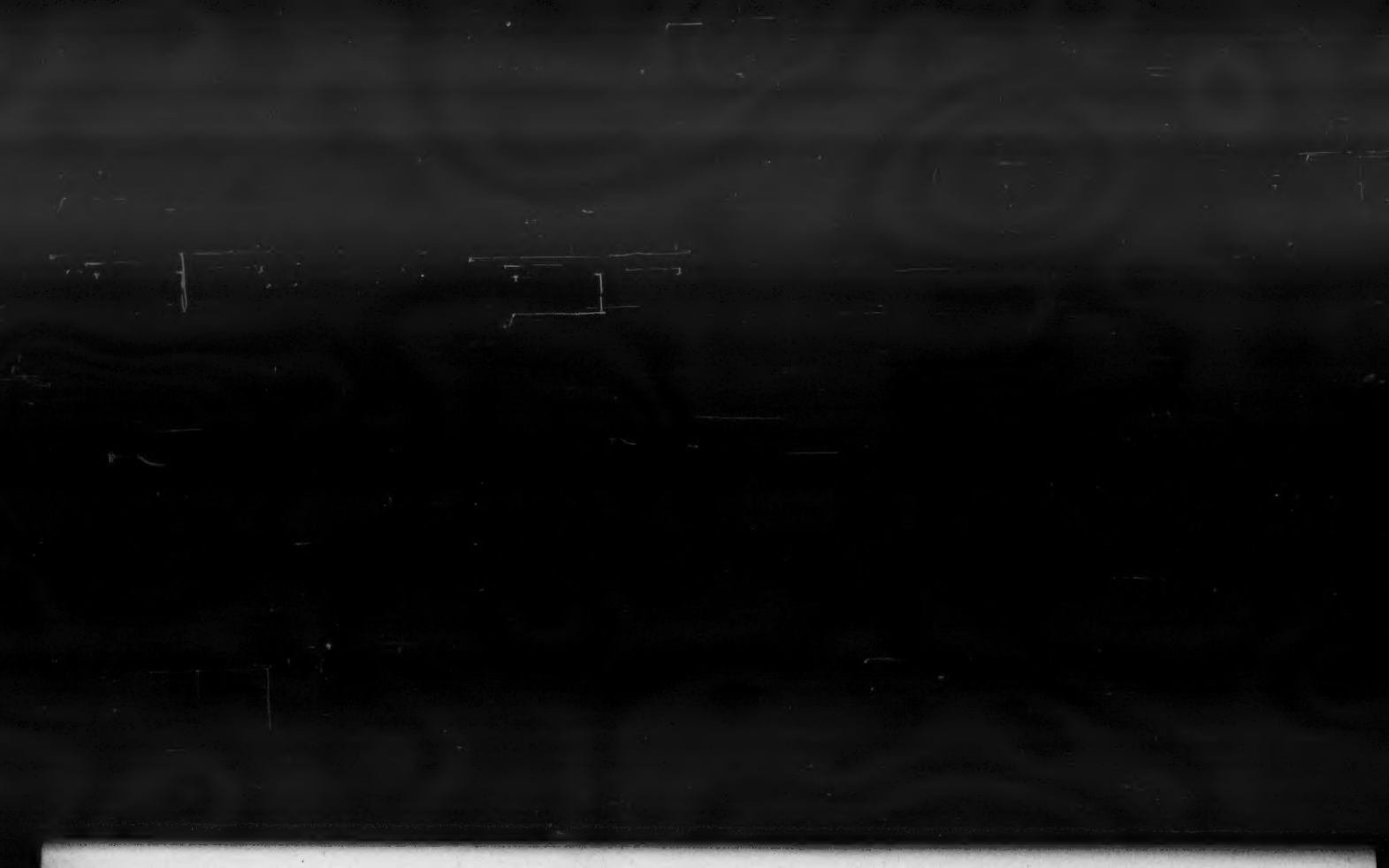
Number of square miles in watershed	2.32	
		Per Square Mile.
Persons living on watershed	509	219
Horses " "	34	15
Hogs " "	67	29
Cows " "	35	15
Privies on "	87	37
Wells " "	29	12
Marshes " "	2	
Pastures " "	9	
Sewage disposal field "	1	

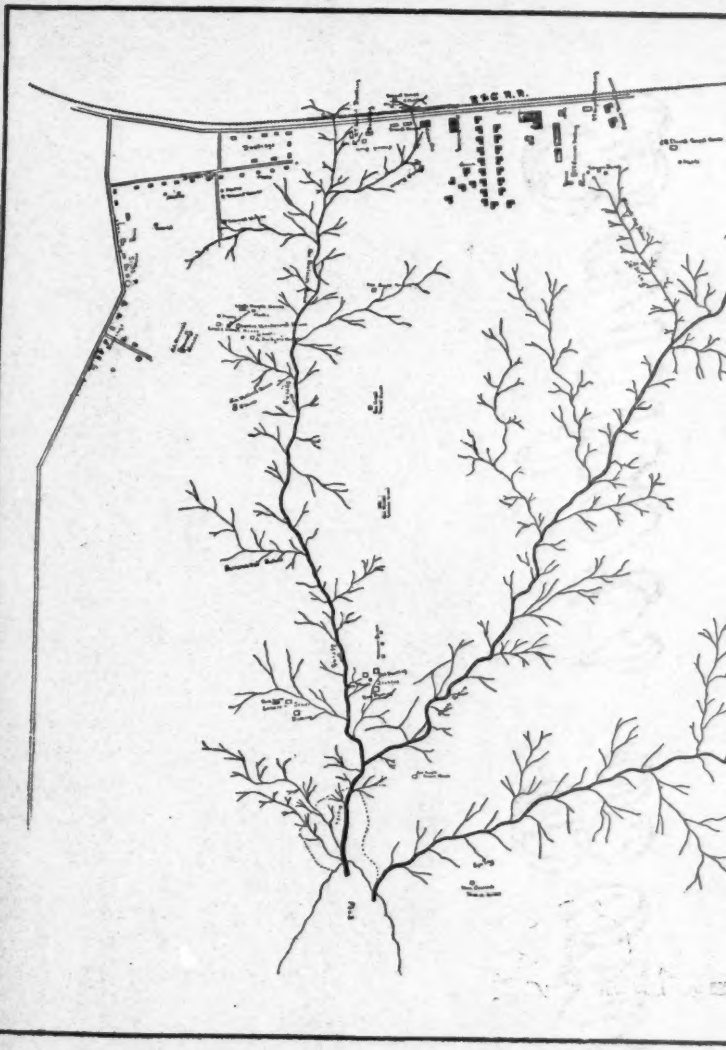
A sanitary map was prepared to show the sanitary features of the watershed.

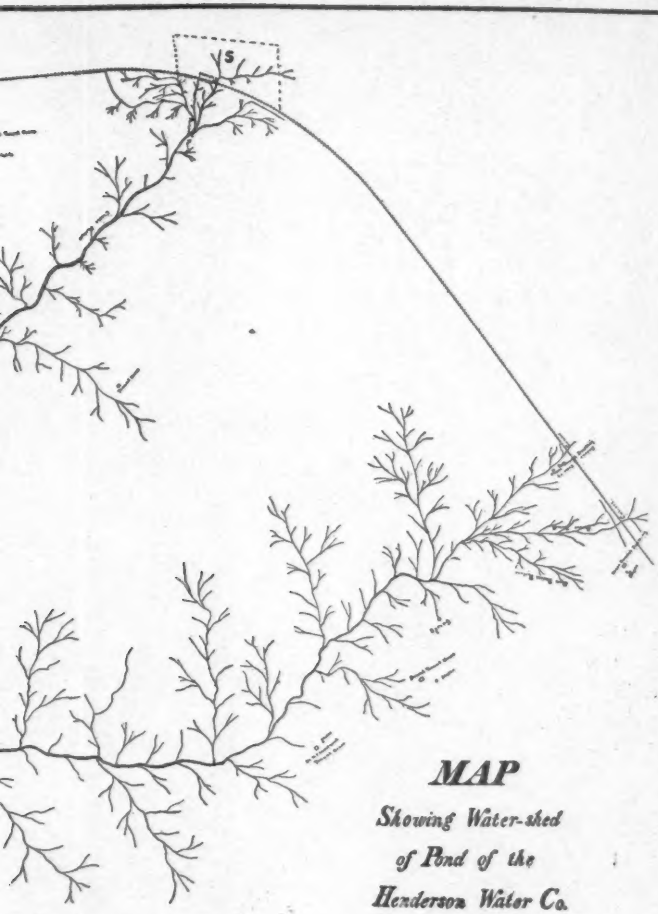
It is readily seen from this that the possible sources of pathogenic pollution are few, and easily controlled.

No privy is within 150 feet of any brook which is a feeder of the reservoir.

The thing which had the most significance from a sanitary standpoint was, that the contents of the town privies were used as a ferti-







MAP

Showing Water-shed of Pond of the Henderson Water Co.

Scale 400 ft to an inch.

lizer on the area marked S; this objectionable practice was easily stopped by the city authorities.

The Raleigh and Gaston Railroad follows the ridge which separates the watershed of the Henderson Water Company from that of the Roanoke River, and only a few rivulets on the other side of the railroad drain into the source of supply.

Owing to the sandy soil on the watershed, very little of the water in the feeders is surface water, except during the freshet seasons.

The springs, which are the main source of supply, furnish water of good quality themselves, but during the spring freshets the water contains the washings from the arable land; the feeders also receive a small amount of swamp drainage which brings with it organic matter and iron.

The three main feeders flow into the reservoir which is formed by a masonry dam in the brook below. The reservoir has an area of about 35 acres and is less than 10 feet maximum depth.

Analyses of the water have been made as follows:

CHEMICAL ANALYSIS BY W. A. WITHERS, A. M., CHEMIST NORTH CAROLINA BOARD OF HEALTH.

Sample collected January 8, 1898.

	Parts per 1,000,000
Residue on Evaporation	56.
Alkalinity	7.2
Chlorine	4.3
Free Ammonia	0.067
Albuminoid Ammonia	0.020

BACTERIAL ANALYSIS BY W. T. PATE.

	Bacteria per c. c.
Sample taken Nov. 5th, '97	78
Sample taken Feb. 5th, '98	184

Owing to the great surface exposed in proportion to the cubical contents of the reservoir, and to the fact that the water is a ground water containing vegetable matter in solution and stored in the sunlight, large numbers of organisms make their appearance during the heated term and the water takes on a disagreeable odor in consequence.

An effort was made to discover the particular organisms which should be the cause of the trouble.

There was no appreciable odor in the water July 16th, when the writer began to investigate.

Several microscopical analyses were made with the results given below:

BIOLOGICAL EXAMINATION.

SAMPLE NUMBER. Date of Collection.	1 July 16. 1898.	2 July 18.	3 July 19.	4 July 20.	5 July 26.	6 July 28.
DIATOMACEÆ.						
Asterionella						
Cyclotella	8	36	14	24	40	48
Melosira	6	8				2
Navicula		4	2			
Nitzschia						
Stephanodiscus						
Surirella						
Synedra			4	2	16	30
Tabellaria						
CHLOROPHYCEÆ.						
Closterium						2
Cosmarium	2	6				
Pediastrum					32	14
Raphidium					8	10
Scenedesmus	8	62	8	4	24	78
Staurastrum	2	18		6	2	30
Conferva						
Protococus	4	136	12	18	32	244
Arthrodesmus						4
Allodorina				6		
CYANOPHYCEÆ.						
Anabaena					68	104
Chroococus	6	4				
PROTOZOA.						
Dinobryon						
Mallomonas		8	6		2	2
Peridinium						
Synura						
Trachelomonas	6	10	2		4	4
Uroglena					2	
Amoeba				2	2	2
Paramecium		14	4		2	6
Englena	4	4		12	2	8
Chaetoglena		2				
Phacus						6
Peranema						
Total Organisms	46	312	52	74	256	594
AMORPHOUS MATTER.	Pr.	Pr.	Pr.	Pr.	Pr.	Pr.
MISCELLANEOUS BODIES.						
Insect Parts	Pr.	Pr.	Pr.	Pr.	Pr.	Pr.
Ova and Zoospores	28	22	22	14	10	8

Pr.=Present.

No trace of cristatella was found in the samples by microscopical methods.

The figures are to show the number of organisms per cubic centimeter.

These absolutely failed to account for the odor in the water.

July 16th, a growth of cristatella was discovered (C. mucedo) on the sides of the outlet flume.

July 18th, the water had an odor exactly similar to that of the crushed masses of cristatella.

This state of affairs continued as long as the writer remained in Henderson. The odor however increased and decreased directly as the temperature and inversely as the amount of rainfall.

By July 20th, the masses of cristatella had grown to enormous size, especially about the piles which are driven on either side of the suction pipe.

A boat could be filled in a short time with the yellowish white, translucent colonies, many of which were a yard in diameter.

Subsequent tests with these colonies showed that they imparted the disagreeable odor to the water and that it was a secretion of the organism and not the organism itself which was the specific cause of the odor.

Whether this odor is the odor of the fæces of the organisms or not, I am unable to say.

Cristatella occurs at Henderson every summer, and the organism grows in noticeable amount between July 1st and September 15th. This year the appearance of the odor was delayed as is explained below.

Cristatella, or to be more specific, cristatella mucedo is one of the polyzoa or "moss like" animals, called so from the appearance of its colonies. The life history of cristatella is about as follows:

The adult individual is a colonial, worm-like animal with the digestive tract flexed on itself so as to bring the anal opening very near the mouth. This mouth is surrounded by finger like tentacles, and the tentacles in turn are covered with cilia (or hairs.) These cilia are capable of producing currents of water about and in the mouth of the animal, thus bringing its food within reach.

The animal has a very simple circulatory system, the blood being in one cavity, and each individual has both male and female sexual organs.

The large colonies mentioned above are produced from the parent by the process of budding. At the same time statoblasts or winter

eggs are produced, some of which survive the animal and the next winter season. These statoblasts are flattened spheroidal bodies, surrounded by a row of hooks which serve to fix the egg to some convenient spot.

The outer rim or ring consists of float cells and the egg substance is held between two watch glass like covers.

Many of these statoblasts can be observed floating on the surface of the water during the summer, but because they float they are not likely to be pumped into the mains, the intake being 8 feet below the surface.

The next season these statoblasts hatch and produce a free swimming cristatella, which soon attaches itself to a favorable spot and produces in turn a new colony by the process of budding, thus completing the cycle of its growth.

On account of its size and habit of growing in colonies, it is not surprising that the microscopical analyses did not reveal their presence.

The colonies grow about or are attached to articles on the sides and bottom of the reservoir, as is well known to you all. The individuals are imbedded in a structureless jelly, each having a cell out of which it can raise itself slightly. This jelly is analagous to the shell of an oyster or barnacle and is therefore the habitation of the animal.

Cristatella is strictly an animal organism and is dependant for its growth upon :

(*a*)—Food.

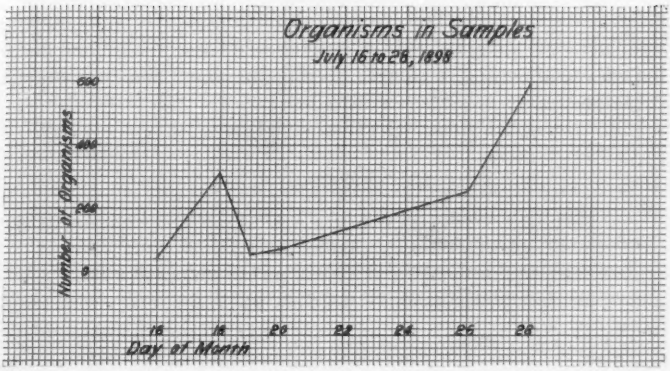
(*b*)—Temperature.

(*c*)—Sunlight.

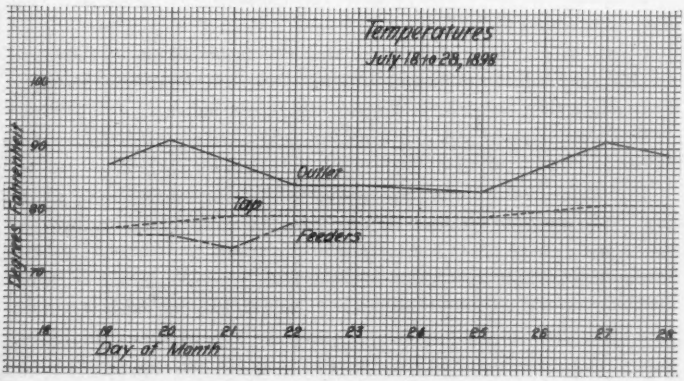
(*a*)—Its food consists of the organisms present in the water at certain seasons of the year.

It evidently grows best when the other organisms are most abundant, *e. g.* July 16th, when there were only 46 organisms per cubic centimeter of the water, there was no considerable growth and no appreciable odor, but two days afterwards, when the organisms numbered 362, the evidences of cristatella were unmistakable.

(*b*)—The temperature seems to be the chief factor which determines the growth of cristatella.



It seemed, from the short experience at Henderson, that the temperature of the water must rise to about 85° F, before any marked odor was produced. The curves plotted for temperatures and days are given below, and it can be stated that the high points are coincident with the strongest odor.



With such a shallow reservoir, the water is frequently changed, but between July 18th and 25th, when the average daily flow was about 3,000,000 gallons, the increase in temperature, due to absorption of heat in passing through the reservoir, varied between 10° and 15° Fahr.

This year the appearance of cristatella was very much delayed.

This was undoubtedly due to the unusual amount of rain, and the consequent increased flow through the reservoir, it being apparently impossible to heat such a large body of water high enough to induce the growth of cristatella during the short time it remained in the reservoir.

(*c*)—Cristatella grows only in the light and is an organism of annual occurrence.

Such was the difficulty at Henderson, and the problem presented was to remove the odor caused by the growth of cristatella and the turbidity and pollution due to the spring freshets.

As the ground water in the vicinity of the pumping station could not be utilized for the amount of money at the disposal of the Henderson Water Company, owing to the character of the water bearing strata, the writer planned a filter plant in combination with an ærator, and recommended the Warren filter as best suited to the purposes. There is nothing especially novel about any of the features of the plant, except perhaps the ærator. The ærator rests on top of the settling basin of the Warren filter and consists of a series of shelves arranged in the form of a pyramid.

The base of the pyramid is 5 feet square and there are four shelves on each face of the same.

On the edge of the shelves are strips of brass which are arranged so that they can be adjusted in such a way as to permit the water to fall in a thin sheet or in drops to the shelf below.

The whole ærator sets in a tank which in turn rests on the settling basin.

The water from the pump passes through the ball nozzle at the top of the ærator. It then impinges on the copper plate above and falls back down over the shelves into the tank.

The water then passes through the filter into a clear water basin and is thence pumped to the town. Ample contact with the air is thus provided for and the cost of pumping water the few additional feet higher necessary is less than that of a compressed air plant furnishing 1½ gallons of air to every gallon of water treated.

The size of the filter is 12½ feet and the nominal capacity of the whole plant is 300,000 gallons daily.

At present the water has an odor like that of decaying oyster shells and the improvements will undoubtedly be appreciated by the community and authorities during the summer of '99.

DISCUSSION.

THE PRESIDENT. Gentlemen, Mr. Weston's paper is now before you for discussion.

MR. HASKELL. I would like to ask Mr. Weston if the presence of 100 anabæna per cubic centimeter in the water made any perceptible odor?

MR. WESTON. I did not detect the characteristic odor of anabæna at all, excepting when we concentrated the organisms. We concentrated a half a litre or pint of water down to half an ounce for analysis, and in that concentrated mass we were able to detect the odor of anabæna, but in the tap water I detected no such odor. It has a peculiar odor as you know.

MR. HASKELL. I would like to ask how far the water passed after it got into the pipes before it reached the tap; that is, the length of time it would probably be in darkness instead of light.

MR. WESTON. I couldn't tell you about the length of time without some calculation. The main pipe from the pumping station to the town is a 12-inch pipe, and the daily consumption is only 75,000 gallons. I think the tap I took the water from is 11,000 feet from the pumping station, and I should say the water would be in the pipe at least a day and a half.

THE PRESIDENT. Mr. Hollis, won't you say something on the subject?

MR. HOLLIS. I was particularly interested in what Mr. Weston said about the presence of these organisms escaping detection, owing to the fact they were not brought in through the pipe. That emphasizes what we find to be true of many growths, that field work must be combined with the laboratory work oftentimes in order to detect the real cause of an existing trouble. Many times these minute organisms are localized and occur from some particular local cause. It is interesting to know that Mr. Weston had the same experience with the larger organisms, for most of our experience has been with the smaller growths.

MR. HASKELL. I would like to ask if, before deciding to use the Warren filter for this purpose, Mr. Weston made any study whereby it became evident that a mechanical filter would be cheaper or more expensive than a properly constructed sand filter?

MR. WESTON. It happened the water company could purchase

a second hand Warren filter, and that largely determined the policy of the company. I think without a doubt a sand filter would have cost a great deal more. For the removal of organisms I think a filter can be run at a much higher rate than for the removal of bacteria, because in this case the filter acts as a strainer, nothing more or less, and it is expected to have no other action. We haven't got to wait for the film to form around the sand before it will operate. We haven't got to wait for the settlement of any amount of suspended matter. The point is that the ærator does the work of removing the odor, and the filter strains out the organisms, thus preventing the further formation of the odor. The cost of the mechanical filter plant, which is now in the process of construction there, is estimated at about $7,000. I think $35,000 an acre is a fair estimate for a sand filter, and, if I am not mistaken, about a quarter of an acre of ground would have been required.

MR. HASKELL. Is it not really more important, in the case of a water supply of this character, to entirely remove the bacteria than it is to remove the organisms?

MR. WESTON. As I remember the bacteriological analysis of the water made by the State Board of Health of North Carolina, there were 230 bacteria organisms per cubic centimeter in the water, which is not considered at all excessive for surface water. The water is practically a ground water, and were it not for the washings of the arable land and the storage in the reservoir, it would be an excellent water. It has no color at all, or a very slight color, and is a pleasant drinking water, soft and palatable, but the plant was badly designed. It seems to be the idea of some contractors who put up water works, that if they erect a standpipe and lay their distributing system, and then run a suction pipe out to where it is a little damp, they will have a good water supply. And so they dammed up this pond, which is only 4 feet deep for the main part, and less than 10 feet deep at the deepest place. Such a reservoir, of course, furnishes the best conditions for the growth of organisms. Then to make the matter worse, the original builders of the pumping plant built it at the foot of the lake, where the organisms are the thickest. At the upper end of the pond the water is fully as good as it is in the feeders, but at the lower end it is simply foul, smells like a decaying heap of oyster shells, and it is unpleasant to bathe in.

MR. HASKELL. My reason for asking the question is that I judged here was a watershed which would be very liable to get impregnated with typhoid germs. It seemed as though there would be quite a population which might perhaps contribute infection to the plant, and that the dangerous element, which we have to fear in our water supplies, would not be as likely to be eliminated by this process, as by a good sand filter.

MR. WESTON. In making the sanitary survey of the watershed, Mr. President, that matter was looked into quite carefully; and, while there might be some danger, there is no privy which is located within 100 feet of any visible stream on the watershed. The soil is a fine sand, and it might be said that the whole region is an excellent filter to begin with. If there were any pollution there I hardly see how it could get into the reservoir. The climate also is in our favor, because in North Carolina they have no snow to wash down from the sides of the valley into the streams in the spring, carrying with it all the dejecta which may be thrown on it during the winter. Then there is another factor, that a mechanical filter well managed will remove a large per cent of the bacteria in water. Having these two facts before our minds—the fact of the natural protection afforded by the sand of the watershed, and in addition to that the mechanical filter—I cannot see how the sanitary features of the problem are of very much consequence.

MR. HASKELL. What is the death rate of the population per ten thousand from typhoid fever if you have information as to that?

MR. WESTON. I am unable to give you any facts about that at all.

MR. CHACE. My father was a physician, and I used to hear him say that when a sufficient cause for a man's death was found, it wasn't worth while to look further; for instance, if a man's head was off that was sufficient to cause his death, and there was no need to look for anything else. I understand in this case Mr. Weston was called in to ascertain the cause of a bad odor which was giving a great deal of trouble. He found that cause and found means of removing it. He did not look for typhoid fever germs because there was no trouble from them.

RESULT OF TUBE WELL EXPERIMENTS IN LOWELL, MASS.

BY GEORGE BOWERS, C. E.

[*Read Sept. 15, 1898.*]

Our experiments with driven wells in Lowell were brought to a close on the completion of the third group of tube wells in April, 1897. A description of the first well plant may be found in the Journal of this Association, Vol. IX, No. 2, and of the second in a paper read before you February 12th, 1896. I will now give a brief description of the third group which were constructed under contract by B. F. Smith & Brother of Boston, Mass.

This plant is located on a strip of land lying between the Pawtucket Boulevard and the Merrimac River and owned by the city. It was here that Mr. Andrews made his last tests on the boulevard, as described in my first paper. A line of wells was laid out and driven about 34 feet south of the south line of the boulevard and parallel to it, being about 500 feet from the river. Sixty wells were driven on this line, those on either end yielding so small an amount of water that the line was not extended. Twenty-six of these wells were connected temporarily and pumped four days, yielding 570 gallons per minute. During this test the ground water was lowered 12 feet, and later twenty-nine of the whole number were pulled up, their yield being insufficient to warrant their being retained in the plant.

Another line of 66 wells was then driven parallel to the first and 280 feet nearer to the river; these wells were connected and tested in groups of 20 each, the average yield per well when pumped in this manner being 25 gallons per minute. Samples of water collected from these wells and analyzed showed the presence of free ammonia and iron, in consequence of which they were abandoned and the pipes pulled up. Next, a line of 22 wells was driven at right

angles to those connecting with the line first driven; when these wells were tested all but five proved good.

The next wells were laid out and driven in a line parallel with the first two lines described and 170 feet south of the one first driven. In this line are 122 wells which have been tested for quantity, in groups of from 15 to 20 wells each. When the water here was analyzed, each and every well was found to be of excellent quality. The plant contains 169 2½-inch wells, which vary in depth from 27 to 40 feet. They are driven wells and a very large point was used to protect the screens in driving. The screens used here are similar to those used at our second plant and vary in length so as to correspond with the depth of the water bearing stratum at each well; this lies about 25 feet below the surface and varies in depth from 5 to 15 feet. The earth above this stratum is composed of very fine sand and river silt, which is almost impervious to water. Between this bed of water bearing sand and bed rock is a very fine sand known as quicksand, varying in depth from 30 to 40 feet, in which no water is found, even at the surface of the rock where it is generally found. The wells are connected by flanged suction pipe of the following sizes:

20-inch	suction	pipe		13 feet
14 "	"	"		1,152 "
12 "	"	"		326 "
10 "	"	"		170 "
8 "	"	"		130 "
6 "	"	"		265 "
			Total	2,056 feet

On every length of the suction pipe is cast a 2½-inch branch connection, at an angle of 45 degrees to the main pipe; this causes all the pipe to be classed under the head of specials. This, we think is far better than the custom of connecting one or two lengths of pipe with a short branch special, as it greatly reduces the number of joints, a very important item in work of this kind.

The connection of the suction pipe with the well is made as follows: Into the branch is screwed a piece of 2½-inch pipe, to which a gate of the same size is attached; next is placed a piece of lead pipe about 3 feet long with a flanged joint nearest the well, and last, a piece of 2½-inch pipe of the right length to make the connection with the curved Tee joint at the well. This is a very easy way to

connect the wells, as the lead pipe may be used to correct any small error in line or grade, a difficult undertaking with iron pipe. A lead pipe should never be used for a water supply until you have ascertained that it will have no effect upon it, and as the service pipes in our city are lead, this is the first problem we had to solve.

The suction mains are connected with a large horizontal air receiver, 11 feet long and 6 feet in diameter, and each pump is connected independently with the receiver. The suction mains are laid about three feet below the surface of the ground on a pile foundation, on a true grade declining from the pumps. Great care was taken by the contractor in making the suction mains, branches, and all connections air tight. Every pipe and special was tested for air before it was laid, and to our great surprise many of them which had passed the water test were found defective under this test. Of the first shipment of pipe more than 50 per cent was found by the air test to be defective and was returned to the foundry. Most of the small specials found in stock were defective also, and the contractor was obliged to order extra heavy ones made to meet the test. All the testing for air was done in the field; this was done by connecting the piece to be tested with a pump and forcing air into it while submerged in a tank of water. That this was a wise precaution has been well proven, as this plant has been very free from air.

The air receiver is placed in the pump pit which is 26x28 feet, and with it are connected two 10x18x18-inch Blake pumps, each having a capacity of 3,000,000 gallons per day. As the pumps deliver the water into a conduit only 4 feet above the plungers, their work is very light. Over this pit is erected a temporary building, and when this is replaced by a permanent one, and permanent pumps put in, I see no reason why this plant should not be run by electricity generated at the central pumping station as economically as by a separate steam plant.

The contract for this plant was similar to that of the others, the contractor agreeing to furnish a plant capable of providing a stated amount of water per day during a year's test for a given price per 1,000,000 gallons, and, in addition to this, was paid for all the water delivered which was pumped during said year. On April 30th, my certificate was sent to the water board stating that the contract between the city of Lowell and B. F. Smith & Brother was com-

pleted, and that the contractors were entitled to the full payment for 3,900,000 gallons, also a supplementary contract for 1,500,000 gallons, making 4,500,000 gallons in all. This plant has never been pumped to its limit, the amount of water the contractors were allowed to pump each day being fixed by the superintendent of water works.

The city of Lowell has now an abundant supply of water of excellent quality. The first plant, built by the Cook Well Company of St. Louis, Missouri, was accepted and paid for as a 2,500,000 plant in September, 1893, and it has continued to supply that quantity when wanted ever since. The second plant, built by the Hydraulic Construction Company of New York, was accepted in April, 1896, as a 3,000,000 gallon plant. During its year's trial the company pumped 1,137,961,983 gallons, being at the rate of 3,109,186 gallons per day. The third, which I have just described, we call a 4,500,000 gallon plant, although it has yielded 5,000,000 and is capable of doing so when necessary. This makes a total of 10,000,000 gallons per day when running in a normal condition. This amount could, of course be increased very much in case of emergency. The average amount of water used by the city for the year 1897 was 6,594,364 gallons per day, and the average amount for the month of January, that being the month of greatest consumption, was 7,422,483 gallons per day, showing that for the present at least, we have an ample surplus.

It will be readily seen from these figures that we are not obliged to use our three plants all the time. In fact, one is held in reserve most of the time. By this arrangement any repairs can be very easily made, as either well plant can be shut off and the city's supply of water taken from the other two. The quality of the water has from the first been excellent, and now that the quantity is assured I think we may be entirely satisfied with the result of tube well experiments in Lowell.

DISCUSSION.

MR. FULLER. I would like to ask Mr. Bowers what has been the cost of the three systems?

MR. BOWERS. About $265,000 for the three. I have a diagram here which shows the plan as originally laid out for the well plant,

and the plant as it was finally laid out. You will see that the line we now have is as different from that which was first laid out as is possible to imagine.

MR. WHITNEY. What is the length of the well line?

MR. BOWERS. It is 1,500 feet long.

THE PRESIDENT. You regard it as perfectly successful?

MR. BOWERS. I do. We can pump 4,000,000 gallons a day at any time, and we have pumped 5,000,000 gallons without any trouble whatever.

MR. FULLER. Has Mr. Bowers considered at all what the expense of a filter plant would be of sufficient capacity to produce an equal amount of water from the river?

MR. BOWERS. We always expected to build a filter at Lowell. Some people thought they would like to know whether there was any chance for wells there, though they expected to build a filter, so we began experimenting to find out how much water could be got from wells, the idea being to filter the rest. We built one plant, and then a second, and now we have built a third, and it doesn't look as though we should build a filter. We now have a supply of 10,000,000 gallons, and we use but 7,000,000.

September 16th.

MR. CLARK. Mr. Bowers spoke to us last evening about the supply they have in Lowell from driven wells. As he stated, at the present time the supply is sufficient; but he does not know, and nobody knows how long that supply is going to remain satisfactory. As they draw on the ground more, they may get a less satisfactory supply, and they will find perhaps more iron. And although he appears to be sure that the filter question is far in the future for Lowell, I am not so sure myself. In fact I believe that it will come up in the city of Lowell as surely as the city grows. The question may not be the filtering of the Merrimac river water; it may be the filtering of the well water.

MR. FELS. I should like to say a few words, Mr. President, as to the remarks Mr. Clark has made about the Lowell supply. Our experience there teaches us that as our plant grows older it will deliver more water. The reason for that seems to be that the more we pump from the wells the easier the delivery is. Of course we cannot tell absolutely what the yield will be four years from now, neither do we know whether the Merrimac River will carry as much

water in ten years from now as it does today. A great many people in our city said we could never get a million gallons of water a day from wells, but we have demonstrated that there is no trouble getting ten millions. And as to the cost, as Mr. Bowers told you last night, it was only about $150,000, and I believe the city of Boston has paid four or five times as much as that for its surface supply. I see no reason why the amount of water should grow less, because after all there is really no question but that it is really surface water. Last year, during the summer when there was hardly any rain for three months, our wells delivered three millions daily. We draw to a depth of from 40 to 60 feet from a territory of 35 or 40 miles, and it certainly doesn't seem as though there was any danger of a lack of supply, and our experience during four years has proved that, we think

MR. CLARK. I did not intend to say that the volume of water drawn from the wells is going to grow less year by year, but as the city grows, I suppose they will have to draw more water. Whether they can keep extending the well system or not is a question, something I don't know about—a man who has investigated it of course knows more than I do about it—but the limit will probably be reached eventually in the vicinity of Lowell, and as I have said, they are not sure that the water is going to continue to be of the same quality it is today.

SOME THINGS THAT SHOULD BE DONE IN CONSTRUCTING A DISTRIBUTING SYSTEM OF WATER WORKS.

BY WILLIAM R. HILL, CIVIL ENGINEER, SYRACUSE, N. Y.

[*Read Sept. 14, 1898.*]

In building a distributing system of water works great care should be taken in selecting the most perfect materials and constructing the works in the best possible manner to insure durability.

With the operation of the primitive works began the necessity of making repairs, and with the most perfect construction of this day we find that we are still making repairs. The question that presents itself is how can we construct a durable system and reduce the necessity of making repairs to a minimum. We should secure careful and competent engineering ability to devise the plans and specifications, the most perfect fixtures should be adopted, all the material should be made subject to a rigid inspection, and none but competent and reliable workmen should be employed.

In many municipalities but little attention is paid to the inspection of the materials. It is important that the cast iron pipe should be inspected during every stage of its manufacture, both as to the quality of the metal and the workmanship. It is not the intention to cast any reflection on our manufacturers, but still it is a fact that without a rigid inspection their employes will become careless and cause a poor material to be put on the market, even though it is the desire of the manufacturer to furnish none but the best possible; this is true not only in relation to the manufacture of pipe, but to all the materials and fixtures used.

Special attention should be given to the form of the lead groove in the hub of the pipe; it should be of such a shape that it will permit the lead to be easily driven and gradually expanded.

The pipe should be laid in a straight line and on a grade without any abrupt angles in order to insure a uniform space in the joint for

the lead. The pipes should also be in lines located a uniform distance from the center of the streets so that they can be easily found. No joints should be run or caulked until the pipe is placed in line in the trench. It might be a little cheaper to join three or four lengths of pipe together before they are lowered in the trench but there is a liability of injuring the joint. No short pieces of pipe without a proper spigot should be used at any end, as the pressure will tend to open the joint. Bends should be made by using special castings and not by using short pieces of straight pipe. There should be a block of masonry built back of all bends and hydrants as well as against the ends of all lines of pipe that are eight inches or larger in diameter. After the pipe is laid it should be subjected to a pressure test of at least one hundred pounds per square inch more than can be obtained from the ordinary pressure under which the plant is to operate. The pipe and joints should be carefully examined while they are under pressure and if any defects are found they should be corrected before the trench is filled. A section of pipe should be very slowly filled with water, otherwise it would be subject to a severe shock by the surging of the water. Hydrants or other fixtures should be open for the escape of the air otherwise it would be apt to burst the pipe.

When good pipe has been properly laid the necessity of digging up the street to make a repair should be quite remote. I think that it is fair to say that the greater number of defects found in a system of water works are the occasion of the little attention paid to the selection of the material and to workmanship of the service pipes.

All corporation and curb cocks should be made subject to inspection during all phases and processes of their manufacture. They should be made of a mixture of metal that will insure a strong and tough casting. A good casting for this purpose can be made of 88 parts of refined copper, 6 parts tin, 3 parts lead and 3 parts zinc. If there is alkali or salt in the soil where the cocks are to be used the zinc should be omitted, as the alkali and salt will corrode and destroy it.

The castings should not be allowed to cool in the sand. From 15 to 20 minutes after they have been poured, depending upon the heat of the metal when poured, they should be placed and allowed to cool in water before the sand is removed. This operation anneals the metal.

The cocks should be made strong in all their parts, with little regard to the saving of an ounce or so of metal. The plugs should be lubricated by plumbago and Albany grease or vaseline. Beeswax and tallow should not be used as it will get hard and make it difficut to open or close the valve. The finished cocks should be tested by hydraulic pressure of not less than two hundred pounds per square inch and while they are under pressure the valve should be opened and closed and examined to see if there are any defects.

The selection of an inspector should be made by considering both the practical and theoretical knowledge of the applicant. If a party could not be found with both these qualifications, I should prefer the practical man, because he could point to faulty work with great confidence, and with his years of experience, he should have some knowledge of metal. The inspector with only theoretical knowledge is apt to accept poor and reject good work.

Service pipes should be laid in straight lines at right angles to the axis of the street so that at a time of a leak the location of the corporation cock could be easily determined from the position of the curb cock. This together with the fact that the main is laid at a fixed distance from the centre of the street will enable the repair to be made with the least possible disturbance to the pavement.

If the service pipe is of lead all the solder joints between the main and curb should be made in a shop, as better work can be done there than in a trench. To one end of the pipe the tail piece of the corporation is soldered, while to the other end the curb cock and a piece of pipe about a foot long is attached. The pipe is then coiled up and taken to the trench where it is to be used. The tail piece is attached to the corporation and the service is complete to a point one foot beyond the curb cock where the joint connecting with the service to the building is made. None but the best of solder for the purpose should be used. The service pipe between the main and the curb should be made of one piece and no unnecessary joints should be permitted. All short pieces of lead pipe can be melted up and used for caulking joints in cast iron pipe.

A service pipe should not be laid in the same trench or close to a sewer. It would be hard to discover a leak should one occur in such a service, as the water would not appear on the surface of the ground but would find its way to the sewer.

Where a sewer or other trench is excavated crossing under a lead service-pipe, the pipe should be properly supported, as when the trench settles it would carry the pipe with it and would be apt to cause a leak at the nearest joint.

Fire hydrants should not be used as fixtures to fill sprinkling carts with water, unless they are provided with a special valve and nozzle for that purpose. Such a valve and nozzle can be made in the dome or cap of the hydrant. During the season when sprinkling is done the drip is closed and main valve in the hydrant is slightly opened so that there is a constant supply of water in the barrel of the hydrant. The men who sprinkle cannot interfere with the main valve or nozzles as their wrench will not fit them. To use these hydrants for fire purposes the firemen first close the main valve with three turns of the valve-rod. They cannot make a mistake and take off the upper nozzle as that requires a smaller wrench. No one but a fireman or an employe of the Water Department should be permitted to have a wrench that will open the main valve. These special hydrants should be placed at points convenient for the purpose of sprinkling. In the city of Syracuse, N. Y., there are two hundred that have been in use two years, and have been very satisfactory, both to the Water and Fire Departments.

A frequent cause of trouble with hydrants is because they are not properly drained to a sewer. If this connection were made with a lead or wrought-iron pipe there should be no liability of the hydrant becoming frozen.

The establishment of a system of water works with the best material and workmanship, will result not only in a saving in the cost of repairs to the plant and to the pavements, but there will also be a saving in the cost of pumping water that would be lost in leaks, and this might be considerable.

In conclusion let me say that it is to the great credit of our manufacturers that they have kept their products up to the present standard. If poor goods have been used it is in a great measure the fault of the purchasers, who have accepted the lowest proposal for furnishing goods, without any inspection of the metal or weight or workmanship of the fixture, and have rejected the proposal of parties who have given their product a life's study, and have struggled in competition with others who furnish fixtures of light weight, poor workmanship and of a metal composed of a mixture of scraps.

DISCUSSION.

THE PRESIDENT. Gentlemen, Mr. Hill's paper is now open for discussion. He has covered quite a wide range of topics, and I think there ought to be something said upon some of them.

MR. FULLER. I would like to ask Mr. Hill in regard to his hydrant, what make it is and where it can be obtained?

MR. HILL. The hydrant we use is the Eddy, but the fixture of which I spoke can be attached to almost any hydrant.

MR. CHACE. Mr. Hill spoke of the form of groove of the hub of the pipe. There are two forms in common use, that in which the section is semi-circular, and that in which the section is a V. I should like to ask what he prefers and his grounds for preferring one over the other.

MR. HILL. I prefer the one which you have described as in the form of a V, the inner surface of the hub being for about an eighth of an inch or quarter of an inch parallel with the face of the pipe, then curving inward about three-eighths of an inch in a distance of an inch and a half and then outward again in about half an inch of distance.

MR. CHACE. The reason I asked the question was that I have heard it claimed as an objection to the semi-circular form that, after the joint had been poured, when the lead was caulked it would be driven by and cut off. And that the V-shaped avoided that difficulty. Now, practically, I don't think it makes any difference what form that groove has. I have had occasion to take up a good many pipes, and I have seen joints with the semi-circular form which were entirely perfect, that hadn't been driven by at all; and practically, in the form of the hub, the founders do not succeed in getting the theoretically perfect form of V which should be desired. So I really believe you get fully as good results from the old-fashioned semi-circular form.

THE PRESIDENT. The depth of bell is usually a prolific source of discussion, and I believe there is a wide difference of opinion among the members as to the proper depth to use on the same sized pipe. Will you say something on that subject, Mr. Whitney?

MR. WHITNEY. I am not prepared to say much on the subject, but of course we all know that there are hardly any two adjoining localities where they use precisely the same pattern or the same

depth of bell. While some people think that about 4½ inches is the right thing, others would get along with perhaps 2 or 2¼ inches. If there was a representative here from Providence I presume he would tell us about the Providence or Shedd bell, which is used there and in a large number of other places. Of course a shallow bell necessitates using more special castings than a deeper bell, but, on the other hand, you don't have to use quite as much yarn and perhaps not quite as much lead. I think an interesting paper for the Association would be one which would treat on the different patterns of bells that are in use, and the depth of lead, etc., required. The subject is certainly broad enough for one paper and perhaps for two. I would like to ask Mr. Hill what is the depth of his bell?

MR. HILL. I prefer 4 inches. On some of our smaller pipe, 6 and 8-inch, I have used 3½, though I would rather have 4.

MR. HAWLEY. We frequently see specifications which say: "Joints shall be well and properly caulked," or words to that effect; and it seems to me that a subject which might profitably be taken up here would be just what "well and properly caulked" means. We frequently find workmen differing in regard to the proper method of caulking a joint, and I would like to ask Mr. Hill what his ideas are on that subject.

MR. HILL. I like to see the lead driven to about an eighth of an inch inside the face of the hub, for then I feel pretty well satisfied it is well driven, and with the inspection of the pipe under pressure it is a pretty good guarantee you have got a good joint. On the conduit line from Skaneateles Lake to our reservoir we tested the pipe with 100 pounds greater pressure than it can get from the lake, and examined all the joints while under that pressure. We found a great many of them which would sweat, as we term it. When we started work the contractors tried to get us to omit the clause about making the test, claiming that they had workmen who had been caulking joints all their lives, and they guaranteed none of them would sweat. Well we turned the water on that conduit line in July, 1894, and the gates at Skaneateles Lake have never been closed since. We have a patrolman walking over the line every day, but we have never found a leaky joint on the line.

MR. HAWLEY. That will do very well on a conduit line where it is possible to make such a test, but on the distribution system in a

city frequently the line must be covered up so quickly that such a test cannot be made. And when it comes to the matter of inspection, the inspector finds fault with the caulking, the contractor says he is doing the work in a workmanlike manner, etc., and the question is what that consists in? Of course if a joint is driven back it is pretty good evidence that it is tight, but still if loose yarn is used it will drive. Now, what I am coming at is whether it wouldn't be a good thing to specify the working tools which shall be used, beginning with a cold chisel, and then following with the various sized tools? I have made it a practice to do that, and in cases where inspection under pressure cannot be made it seems to me that a specification of that kind would cover the matter pretty well.

MR. HILL. I am not prepared to discuss the question as to tools, but I cannot comprehend any case where you wouldn't have an opportunity to inspect the pipe under pressure. I have laid 140 miles of pipe in Syracuse, some of it in our principal business streets, and I have always tested it before it was covered.

MR. HAWLEY. I remember one case on new construction where we didn't have the pumping station built until some months after the distribution system was finished. How would you make the test then?

MR. HILL. If you can fill your pipe with water from any source at all, having it once filled you can get your pressure from a hand-pump.

MR. FULLER. In several cases where I have had heavy pressure, I have had lugs cast on the hydrants and also on the special casting at the other end of the hydrant branch, and simply run a rod through and put a nut on at each end. That answers a very good purpose and, perhaps, would not be as expensive as the block of masonry which Mr. Hill speaks about. I think it is a good thing to have something to hold your hydrant on, because, of course, there is one joint where there is no bead on the pipe, and if the pressure is heavy it is very likely to push the hydrant off, and the same with bends.

MR. HILL. I quite agree with Mr. Fuller, that the rods would answer the same purpose, but they don't cast lugs on the ordinary special. I will say that in testing our 30-inch pipe where we had a special casting which formed a curve, the castings were 8 feet

long and 14 feet radius, and there were five of those put together to make a vertical curve. When I put the pressure on there without any support on the top of the pipe, the pressure lifted that 30-inch pipe right up.

MR. FULLER. I think in such cases, when conduits cross bridges, where you have to put in two eighth bends, for instance, there isn't any doubt that those pipes ought to be thoroughly strapped together; because it is usually a place where, if a leak occurs, it is apt to do great damage. I have found that out by experience. I have never had any bad accident, but I have had cases where it might have been pretty serious if it hadn't been discovered in time.

MR. CRANDALL of Burlington. I would like to ask Mr. Walker if it is his custom to test the pipe when he re-lays his cement pipe in the streets?

MR. WALKER. I do just the same as the rest of the sober superintendents do, or most of them, I guess. I lay a pipe in the street, and I back fill it, and then I trust to luck whether it will leak or not. (Laughter.) You may test it as much as you are a mind to and find it all right, and in two years' time it may leak. So I do the best I can, lay it the best I can, have it caulked the best I can and back fill the trench, and then folks won't kick about the street being dug up and all that, and if there is a leak afterward I mend it; and I guess that is the way the majority of superintendents do. (Laughter.) I don't know as I can offer anything new or make any suggestions on this subject. We have had all kinds of contractors to lay pipe and they have said that they have laid it perfectly, they have tested it and we have tested it, but after they have been away about a year I find it leaks, so I have concluded they don't do the work any better than I can do it myself. I for one never saw any pipe laid but what would leak. Others say they can lay it so it won't leak. I have heard them get up here and tell us how they can do it, that it is easy enough (laughter), but I never could do it. I am rather inclined to think that there are some cases where, do the best you can, there will be some settling. For instance, you are obliged sometimes to lay a pipe in a hurry in a pretty bad, wet place, and it is apt to settle the best you can do. I am not going to sit up nights to see if it settles, but I back fill, and do the best I can, and trust to luck, more or less. (Laughter.)

MR. HASKELL. I would like to ask Mr. Hill if he can tell us how many leaky joints he discovered, or what percentage of leaky joints, during these tests which it was necessary to re-caulk before the trench was filled?

MR. HILL. I don't know that I can answer that, but to my best recollection in the first half mile of pipe we laid, we found in the neighborhood of twenty joints that were leaking a little, oozing, sweating as it were.

MR. HASKELL. It is very difficult to caulk a joint so it won't sweat a little bit. Of course we cannot expect to get perfect work, but in most instances that I have known of tests being made of our work it was not necessary to use a caulking iron again, and we do not expect to have to re-caulk a joint. I often put in several miles of pipe and there won't be a joint that a caulking hammer has to be used on again. While it is quite important that there shall not be leaks, and there are some water supplies which need to save all their water, so it is more important in their case than in others, still it does seem as though with ordinary care the work ought to be so well done, with an inspector on it, that there would not be a single joint from which you could see the water spurt out under a test. I have never found one such joint on our work.

MR. HILL. I would ask Mr. Haskell if he ever has tested his pipe before it is covered up?

MR. HASKELL. We have tested a good deal of our work, until we were satisfied that the caulking we were doing was sufficiently well done so that we could feel perfectly safe in leaving it.

MR. CRANDALL of Burlington. My recent observation of pipe and specials have led me to think the manufacturers are not giving us as good coating as we ought to have or have had in years past. We are getting very cheap pipe and it seems to me we are paying dearly for it. I would like to know if any other of the gentlemen present have been impressed in the same way. I have noticed that the coating we get on pipe and specials coming from the foundries is no better put on than the coating which our local founder would put on with a brush.

MR. WALKER. I think Mr. Crandall is right. It has been my opinion, that of late years they do not coat the pipes as they used to. I am satisfied that the pipe we have laid the last year is not as good as pipe was ten or fifteen years ago, so far as the coating is

concerned. The character of coating of the pipe depends upon the way the coating is done. It doesn't depend so much on the stuff they put on, whether it is tar or whatever it is, as it does on having the pipe and the coating of the right temperature when it is put on. It has got to be done at just the right time, and the materials must be at just the right heat, and then the coating will be good, whether it is tar or varnish or whatever it is. I have more trouble on account of poor coating than I do with bells or leaky joints or anything of that kind. I am satisfied that they don't coat the pipe as they used to, and I should be willing to pay two or three or five dollars a ton more to have it coated as it used to be fifteen years ago.

MR. HYDE. I have found the same trouble that Mr. Walker and Mr. Crandall have spoken of, that the coating of the pipe is extremely poor. In fact, the coating on the pipe we have bought in the last two or three years seems to be good for nothing. My experience has been that the pipe has been growing poorer, that it has been very hard and brittle, and when we get a new lot of pipe a good many of them are cracked at the spigot end, and will have to be cut off before they can be used.

MR. CRANDALL of Burlington. If I remember rightly the city of Newton used to send a man to the foundry to make a very careful inspection of the pipe they would buy. I would like to ask if that is still the practice?

MR. HYDE. I might say that when we put in our works the first 30 or 40 miles of pipe was excellent, the bells and the spigots were fine and everything was in good condition, and so satisfactory that we had no inspector at the foundry. Since then, however, we have bought our pipe at different places and had inspectors go to the foundries and inspect the pipe. But while they have inspected the pipe and seen that the spigot and bell ends were smooth and all right, still the quality of the iron has been poor just the same. I don't know as we can help that, or as any inspector could help it.

MR. THOMAS of Hingham. Allowing that what Mr. Crandall and Mr. Hyde have said is true, who is to blame for it? Isn't it the consumer who is to blame for these poor goods? We demand a cheap article, and they give it to us. We issue proposals for bids for pipe and work, and we give it to the lowest responsible

bidder, and he is going to get out whole if he can. So I think we are really responsible for poor pipe or for poor plumber's work or materials.

MR. HILL. I claim you cannot inspect pipe after it is once coated. If you send an inspector to the foundry during the manufacturing of the pipe the metal can be tested throughout for its transverse and tensile strength, and any defect in the casting can be found before it is coated. If your pipe is brittle and breaks like glass, your inspector has not understood his business.

MR. COFFIN. I never have experienced much difficulty with the quality of the pipe itself, but I have had the same experience that has been spoken of by others with regard to the coating of the pipe. I think the coating is very poor, and it may be that it is due to the change in the methods of coating pipes of late years. The specifications, even those that we use now, require that the bath shall be of a certain temperature, and that the pipe shall be left in it for a certain length of time; I can't give now from memory the time, but it is a considerable length of time. The founders claim it is impossible to do that, that they do not have bath capacity, or yard capacity, or skid capacity enough to allow them to leave the pipe in the bath the length of time specified. Now, it may be that this is an important feature in coating pipes, although I may be all wrong about it. I think the old specifications required that the pipe should be left in the bath something like 20 minutes, that they should be put in a temperature of 300 degrees, and that the bath should be at a temperature of 300 degrees; I am quoting from memory now, but it is about those figures. Now, as nearly as I can learn from the inspectors who go to inspect the pipe, the founders do not want to do anything more than dip it in and get the coating on it and then out with it onto the skids. It is quite possible that that method of treatment may make quite a difference. I suppose their haste is due to the fact that they are rushing out large quantities of pipe. There is a great deal more pipe made and consumed now than there was in the older days, and probably more pipe is made in a foundry of the same capacity now than formerly, and the founders are rushed harder. It has seemed to me for some time that a very serious problem, and one which required the attention of those interested in water works, is the devising of some method for the better protection of pipes.

I think we all believe in cast iron pipe, and that most of us have abandoned the use of cement lined pipe. There is no question that there are serious defects in it, and I guess there are very few who would advocate using it or wrought iron pipe for mains; but there are certain features about cement lined pipe, if it can be well made, which we must admit make it superior to cast iron. As soon as cast iron pipes are in the line they begin to deteriorate.

There is probably no question but the discharging capacity of a cast-iron pipe must grow less, must decrease, as soon as it is laid, with certain waters. Whether this is due to unsatisfactory coating or not I am not prepared to say, and I don't know as I really have any opinion about it; but it seems to be the fact that there is room here for a great improvement. I do not know how it will come. I have been considering for some time in a way for myself, and recently a little more in detail with some one else, the question of lining cast-iron pipe with cement. I do not know whether that is a practical thing to do or not, but I have examined the matter theoretically upon the question of discharge, and I find that a 6-inch pipe lined down to 5¼, (possibly that lining wouldn't be quite enough, but probably a 6¼ pipe could be obtained, and that with a half-inch lining, which would be all right,) would have the same discharging capacity in 15 years as a 6-inch coated pipe which is left in its natural condition. The decrease in the discharging capacity of a coated cast-iron pipe is so great that in about 15 years, and I think that is a conservative estimate, the discharging capacity of a pipe lined down to 5¼ would be as great as a 6-inch coated cast-iron pipe after that time. And of course we all know that the discharging capacity of a pipe in 15 or 20 years from the time it is laid is usually the measure of its value. When the pipe is new the consumption is not usually as great, and the capacity is tested some years later. I do not know and have not examined the matter enough, and of course there has been no practical test made of it, to say that it is a practical matter to line cast-iron pipe with cement; but theoretically, from the point of the discharging capacity, I believe that there will be very little difference in the pipes after a period of 15 or 20 years.

MR. RICHARDS. I think it is perfectly practicable to line a cast iron pipe down so as to make it 5¼ inches; but at first thought it seems to me it would be cheaper to get a cast iron pipe 6¾ inches

in diameter to begin with, and let it rust. It would amount to the same thing in 15 years.

MR. COFFIN. It might be cheaper but not quite as good. There is a difference between a clean pipe and a foul one besides the mere discharging capacity.

ABSTRACT FROM THE REPORT ON THE TEST OF THE SNOW PUMPING ENGINE, AT INDIANAPOLIS, IND.

BY PROF. W. F. M. GOSS, PURDUE UNIVERSITY.

Presented by F. A. W. Davis, Vice President of the Indianapolis Water Co.

5. *Duty as defined by Contract.*—The terms of your contract specify that the duty shall be expressed as the number of foot pounds of work done by the pump per 100 pounds of coal, assuming that each pound of coal evaporates 10 pounds of water. I find that in a test of eight hours duration under the prescribed conditions, 11,725,000,000 foot pounds of work were done by the pump, and that 69,862 pounds of steam were consumed by the engine, giving a duty on the basis stated, of *167.8 million foot pounds.*

6. *Duty on the Basis of a Million B. T. U.*—A more usual basis for calculating duty is to be found in the foot pounds of work done *per million British thermal units* consumed by the engine, the advantage of the basis being that results of tests run under different steam pressures may be directly compared. The engine tested performed 11,725,000,000 foot pounds of work at the pumps on a consumption of 79,093,000 B. T. U.'s making its duty on this basis *150.1 million foot pounds.*

7. *Duty Record Broken.*—The duty disclosed by the data exceeds by a liberal margin that obtained in any test, the results of which have thus far been published. It justifies the conclusion that no engine exists which can equal the performance of the engine tested. The famous Milwaulkee engine, known to engineers the world over, gave a duty of 137. million which is to be compared with the 150.1 million delivered by the Indianapolis engine.

The plan of the test was not sufficiently extensive to permit a complete analysis of all the conditions affecting the work of the engine, but it would appear that the high performance is due to good work by every part of the machine. Not only is the cylinder

economy exceptionally fine but the friction losses are extremely low.

10. *Friction.*—The difference between the work done by the steam on the pistons and that delivered by the plungers, is the work absorbed by the engine in the form of friction. The data shows that but 4.6 per cent of the indicated power was lost in this way. This is unprecedently small. It is altogether probable that a more elaborate test, in which special attention is given to the indicator work, may change this figure since the relation is such that a change of one per cent in the indicated power would produce a change of 20 per cent in the value of engine friction. For the present, however, the figure given represents the best information that is to be had, and there is nothing in the data to discredit it.

11. *Steam Consumption per Horse Power per Hour.*—The performance of steam engines employed in every variety of service is often expressed in terms of the weight of dry steam required per horse power per hour. A determination upon this basis for the engine tested gives a consumption of 11.26 pounds. This, so far as the undersigned knows, is less than is required by any engine the results of which have ever been reported. It is evident, therefore, that the engine excels both in the domain of hydraulic engineering and in that of steam engineering as well.

TEST OF LIFTING WATER FROM WELLS WITH AIR.

Presented by F. A. W. Davis, Vice-President Indianapolis Water Co.

June 4, 1898—11 A. M.

Size of well	10 inches
Depth of well	330 feet
Depth of water above end of air pipe	64 feet, 4 inches
Outlet of Discharge pipe above water in well	25 feet, 8 inches
Lift	25 feet, 8 inches
Tank used—dimensions, length	21 feet, 5 inches
" " width	5 feet
" " depth	2 feet, 6 inches
Capacity—cubic feet	267
" gallons	2,002.59
Length of air line in well including three feet of perforations	90 feet
Size of air line	2¼ inches
Air pressure on meter	36 pounds
Meter used—Wilie Proportional Gas Meter	6 inches

First Test.

Time to fill tank	2 min., 19½ sec.
Cubic feet of air used	152
Air pressure on meter	36 pounds

Second Test.

Time to fill tank	2 min., 12 sec.
Cubic feet of air used	150
Air pressure on meter	36 pounds

Third Test.

Time to fill tank	2 min., 15 sec.
Cubic feet of air used	146
Air pressure on meter	36 pounds

Fourth Test.

Time to fill tank	2 min., 21 sec.
Cubic feet of air used	140
Air pressure on meter	37 pounds

FIFTH TEST.

Length of air pipe.....67 feet
Depth of water above end of air pipe.....41 feet, 4 inches
Air pressure on meter.....46 pounds
Quantity of water required to fill tank.....2,002.59 gallons
Time to fill tank.....2 min., 46 sec.
Cubic feet of air used.....255

SIXTH TEST.

Time to fill tank.....3 min., 35 sec.
Cubic feet of air used.....240
Air pressure on meter.....46 pounds

SEVENTH TEST.

With longer pipe.

Length of air pipe.....110 feet
Depth of water over end of air pipe.....82 feet, 8 inches.
Outlet of discharge pipe above water in well.....27 feet, 4 inches
Air pressure on meter.....44 pounds
Quantity of water required to fill tank.....2,002.59 gallons
Time to fill tank.....1 min., 53⅜ sec.
Cubic feet of air used.....100
Air pressure on meter.....44 pounds

EIGHTH TEST.

Time to fill tank.....1 min., 50½ sec.
Cubic feet of air used.....101

NINTH TEST.

With length of pipe further increased.

Length of air pipe.....129 feet, 4 inches
Depth of water over end of air pipe.....102 feet, 2 inches
Outlet of discharge pipe above water in well.....27 feet, 2 inches
Air pressure on meter.....50 pounds
Time to fill tank.....1 min., 35 sec.
Cubic feet of air used.....100

TENTH TEST.

Air pressure on meter.....43 pounds
Time to fill tank.....1 min., 45 sec.
Cubic feet of air used.....100

ELEVENTH TEST.

Air pressure on meter.....43 pounds
Time to fill tank.....1 min., 43 sec.
Cubic feet of air used.....100

Twelfth Test.

Time to fill tank.....1 min., 45 sec.
Cubic feet of air used.....100

Thirteenth Test.

Air pressure on meter.....44 pounds
Time to fill tank.....1 min., 37 sec.
Cubic feet of air used.....100

Fourteenth Test.

Air line.....4 inches
Length of air line.....111 feet, 1 inch
Depth of water over end of air pipe.....83 feet, 7 inches
Outlet of discharge pipe above water in well.....27 feet, 4 inches
Air pressure on meter.....45 pounds
Time to fill tank.....1 min., 55 sec.
Cubic feet of air used.....105

Fifteenth Test.

Time to fill tank.....1 min., 54 sec.
Air pressure on meter.....45 pounds
Cubic feet of air used.....107

Sixteenth Test.

Using curved nozzle deflecting air upwards 2½ inches.

Length of air line.....108 feet
Depth of water over end of air pipe.....80 feet, 8 inches
Water below discharge pipe.....27 feet, 4 inches
Time to fill tank.....1 min., 48 sec.
Air pressure on meter.....43 pounds
Cubic feet of air used.....99

Seventeenth Test.

Air pressure on meter.....46 pounds
Time to fill tank.....1 min., 47 sec.
Cubic feet of air used.....96
The tests show that the best results were obtained with....129 feet, 4 inches of 2½-inch air line with three feet of perforations.
Temperature at the discharge pipe of the compressor varied from.....176 to 177 degrees
Average time in filling tank.....1 min., 44 sec.
" cubic feet of air used.....100
" pressure on meter.....44 pounds
The lift of water was.....27 feet, 4 inches
The quantity of water discharged.....2,002.59 gallons
Weight.....15,576.66 pounds

The short pipe gave the poorest results. The test by the 4 inch pipe was to ascertain if, by reducing the annular space in the tenth, a greater flow of water would be obtained, but the results did not show it. In all of these tests the temperature varied only from one to two degrees at the compressors and at well. Temperature of water as it comes from well, 54 degrees.

The æration of the water causes it to precipitate the iron rapidly. The air line was covered to a depth of about one-sixteenth of an inch in eight months time.

The tests were made with care and it is hoped they will be of much value to the water works association. The members should bear in mind that the cubic feet is not free air, but compressed. The cooler the air is introduced into the well, so much the better. The contraction of the volume of air occurs when it comes in contact with the cold water and there decreases its effectiveness.

Heat units that will raise the temperature of one pound of water one degree will raise the temperature of one pound of air four degrees.

THE JUNE FIELD DAY OF THE ASSOCIATION.

Wednesday, June 6th, 1898, was the day named for the June outing of the Association. The morning came and it was one of those rare days in June when everybody delights to go afield. The trip as arranged was to include an inspection of the new water system of the city of New Bedford. A goodly number made the start from Park Square station in Boston, which was increased by additions at Mansfield, Taunton and other stations, so that on arriving at the Acushnet station, a few miles north of the city of New Bedford, about seventy-five persons took barges for a drive to the different points. Two or three miles over country roads brought the party to the new reservoir on a high hill in Dartmouth, having an elevation of about 216 feet above tidewater at the city. The reservoir is about 500 feet by 1,000 feet, holding about 65,000,000 gallons, and is divided into two sections, so that either section can be cleansed or repaired without cutting off the supply from the city. The reservoir was full at the time of the visit, having been filled by pumping back from the old supply, the new pumping works not being completed. The reservoir is an example of successful engineering and good workmanship, as no leak has manifested itself since its construction. A description of the works will be unnecessary in this sketch of a trip, as that was very pleasantly done by Mr. Edmund Wood in a paper published in the March number of the Journal for 1897.

Taking carriages again after a walk around the reservoir the party was conveyed to the Braley station on the N. Y., N. H. & H. Railroad, where the 48-inch force main crosses the tracks. Here a train of observation cars stood dumped on a side track. The dumps were soon righted and such planks and timbers as could be picked

up at the side of the track were extemporized as seats. And here we go, most of us standing, some astride the planks, with the engine pushing the train, over a track not the smoothest for passenger service, through the Bolton swamp and across the country, over the four or five miles of railroad which the city has constructed for carrying freight to their new pumping-station. Alongside this railroad is located the new 48-inch steel riveted force main, now all completed and covered in. A ride on a dump-car is not always the smoothest, but it is splendid for observation purposes.

Here on the southern shore of Little Quittacas pond, near the boundary line between Rochester and Lakeville, is located their new pumping-station. At the time of this visit the buildings were nearly completed and the tall circular chimney built of grey brick about 140 feet high was a conspicuous object for a long distance around. The combination of nature and art in the grounds and the buildings when completed will make this one of the prettiest spots imaginable. In the coal house was served a lunch to the hungry travelers. In the engine room workmen were busy getting in and setting up parts of the big pumps, which, when completed, will make this one of the finest plants in New England. Just at this time the workmen were about completing the excavations for the foundations for the gate-house. The work has not been carried along without more or less difficulty from quicksand.

Passing on foot half a mile, or so, along the shore of Little Quittacas, we came to the point where was being constructed the big conduit which is to connect the waters of Great Quittacas with Little Quittacas, across a public highway. The work here is not far advanced, but all was rush and stir. The combined area of the two ponds comprises about sixteen hundred acres, and they are expected to furnish a very fine quality of water. They are located in the towns of Middleboro, Lakeville and Rochester. The chain of lakes in this vicinity comprise an area of about six thousand acres, from one of which the city of Taunton takes its supply.

At the conduit the barges came up again and took the party to the northerly shore of the Great Quittacas, where a narrow strip of land separates this from Pocksha pond, which, further north, enlarges into Assawampsett. Over this strip or neck of land has always been a roadway. The New Bedford people have built this into a broad dam, with a gateway between the ponds; for the Legis-

lature has decreed that New Bedford may have the waters of the Quittacas ponds, and the surplus may flow into Pocksha, but the waters of Pocksha must not flow back into Quittacas. But a short time was spent here and the barges kept on some two or three miles to the Rock station in the town of Middleboro, where cars were taken for a return.

As the party alighted at the little country station they were taken by the good people of the village to be a party of men who had been prospecting the route of a proposed street railway from New Bedford to Middleboro, and it was so reported by the local news-gatherer in the local papers.

PROCEEDINGS

—OF—

THE SEVENTEENTH ANNUAL CONVENTION.

PORTSMOUTH, N. H., September 14, 15, 16.

The headquarters of the Association during the convention were at the Hotel Wentworth, which is in the town of New Castle, about three miles from the railroad station in Portsmouth. The sessions of the convention were held in the hall of the hotel.

WEDNESDAY, SEPTEMBER 14, 1897.

The convention was called to order at 12 M., by President Kent.

The President introduced Mr. F. J. Philbrick, Chairman of the Board of Water Commissioners of the City of Portsmouth, who spoke as follows:

ADDRESS OF WELCOME BY MR. F. J. PHILBRICK, CHAIRMAN OF THE WATER BOARD.

Ladies and Gentlemen of the New England Water Works Association:

I have been requested by our Mayor, who is unavoidably detained (it is absolutely impossible for him to be present with you today, very much to his regret), to represent him on this occasion and extend to you all a hearty welcome to Portsmouth. You will find our latchstring out; we extend to you the freedom of the city. There are many places of interest here on account of their natural beauty and of their historic associations, and we hope you will all enjoy them as far as possible. We trust the meetings of your Association will result in great good in the dissemination of useful

knowledge relative to the business in which you are engaged—in which we are engaged—that of furnishing one of the vital necessities of human existence, an abundance of pure water. I am glad to see such an assembly of so many good looking people here in Portsmouth, who show the effect of cold water judiciously applied. (Laughter.) I trust you will have a profitable session, and that you will carry away with you pleasant recollections of our good old city by the sea. Our Superintendent has prepared a few data concerning our water system here, one of the most ancient in the country, and at some time during the course of your meetings he will have the pleasure of giving them to you. (Applause.)

RESPONSE BY PRESIDENT KENT.

I am sure, Mr. Philbrick, we shall appreciate it very much. In behalf of the New England Water Works Association I thank you for your cordial greeting. We consider ourselves very fortunate in the choice of the place for our present meeting. We meet for social intercourse and for the interchange of thought and experience on a topic which we believe to be of vital interest to every municipality, and we cordially invite all of your citizens who are interested in questions relating to public water supplies to be present at our sessions.

The first business in order is the consideration of applications for membership. The Secretary will read the list.

ELECTION OF NEW MEMBERS.

The Secretary presented the following list of applicants for membership, with the approval and recommendation of the Executive Committee:

RESIDENT ACTIVE.

Frank Baldwin French, Engineer and Superintendent of the Board of Public Works, Woburn, Mass.

NON-RESIDENT ACTIVE.

Edward L. Peene, Superintendent Water Works, Yonkers, N. Y.; Adolph W. Lautz, Secretary Pekin Water Works Co., Pekin, Ills.

The Secretary was directed to cast the vote of the Association in favor of the applicants which he did, and they were declared by the President elected to membership.

The President then delivered his annual address.

ADDRESS OF PRESIDENT KENT.

Gentlemen of the New England Water Works Association:

For the seventeenth time in its history, this Association has to-day assembled in annual convention. Its founders, twenty-seven in number, met at Salem on the twenty-first day of June, 1882, and laid the foundation on which our present organization has been erected—all honor to them, for they not only builded well at that time, but among them are numbered those who have ever been the most active participants in our meetings, and the most zealous in maintaining the integrity and promoting the welfare of our organization.

The most sanguine of its founders could hardly have anticipated the present strength and prosperity of the organization, enbracing, as it does, within its membership, representatives and specialists of every detail of the theoretical science, or the practical work of selecting, building and maintaining a perfect system of water supply.

From the nucleus of a membership of twenty-seven at date of organization in 1882, during the four years ending in 1886 the membership increased to 153; during the four years ending in 1890 the membership increased to 335; during the four years ending in 1894 the membership increased to 443; during the four years ending in 1898 the membership increased to 570; the present number on the rolls; an increase of twenty-one during the past year.

But the strength of our organization lies not so much in the number, as in the character of its membership, the practical value of the papers presented at its meetings and the transactions of the Association as published in its journal, an acknowledged authority on the subjects treated, and a publication of which any association might well be proud. Our financial condition continues prosperous, the treasury having a goodly balance to its credit.

On the death roll of the past year we have to record the name of William M. Hawes, a valued member of this Association. William M. Hawes will be long remembered as an active participant in our meetings, conspicuous for his genial disposition, his ready wit, his keen appreciation of the humorous, as well as for those more stering qualities of character which endeared him to all.

We have held the usual number of meetings during the year. The attendance at the monthly winter meetings has been remarkably uniform, the average being eighty-four and the minimum attendance seventy-five.

The annual field day was held in June, near New Bedford, where through the courtesy of members of the Association opportunity was afforded for the inspection of the detail of one of the largest and most thoroughly constructed plants for the purpose of water supply now in progress, an opportunity exceedingly instructive, which was fully enjoyed and duly appreciated.

Nineteen papers have been presented and discussed at the meetings of the Association during the past year, covering the following range of topics:

Two on the construction of water works systems.
Two on reservoir construction.
Two on pipe laying under rivers.
Two on backfilling trenches.
Two on meters.
One on service pipes.
One on service boxes.
One on loss of water from pipes.
One on handling air in a tube well plant.
One on operating a slow sand filter.
One on methods of obtaining water in the arid Southwest.
One on steel forgings.
One on sinking funds.
One on biology.

To further summarize, we have:

Five on general construction.
Five on special details of construction.
Four on special supplies.
Three on features of operating.
One on biology.
One on finance.
All as relating to water supply.

Of the several topics discussed, one of the most important, and one which is justly attracting much attention at the present time, is that of filtration. Comparatively few of our water works systems furnish water that is at all times, in all respects, everything that

could be desired, and the conscientious official is continually on the watch for improvement, but many are effectually debarred from improvement in this respect by the cost of construction and maintenance as exemplified by many of the filters in operation. It is obvious that in the selection of the source of a water supply no reasonable expense should be spared to obtain the best obtainable, so sufficiently good if possible as not to require any expensive system of filtration, and having acquired such a supply, to keep it free from pollution by proper legislation and proper enforcement of that legislation.

The expense of such a supply would probably be less in the end, and the results more satisfactory, than if obtained by filtration, for it is human nature to prefer water known to have been always free from contamination, rather than filtered sewage, no matter how perfect the system of filtration or how satisfactory the results.

For established plants where it is impracticable or impossible to remove the sources of contamination, and where other supply is not available, there is no other remedy; sooner or later they must filter their water regardless of expense, and the sooner the better; but for new works, expense within the limits of practicability should not stand in the way of securing a pure supply and keeping it so. We should unite in securing the most stringent legislation to prevent the pollution of water supplies and in maintaining and enforcing those regulations.

Of the many advantages to be derived from the interchange of thought and experience promoted by our organization, that by which the smaller works are enabled to profit by the experiences and experiments of those having larger means and facilities than are usually at the disposal of the smaller works, is one of the most important, and I fully appreciate the labor, care and fidelity which their representatives have devoted to the elucidation of methods in their various papers presented to the Association.

In conclusion, I congratulate you on the favorable surroundings of our present meeting, on your continued prosperity as an organization and urge you to manifest the same interest in the future meetings of the Association that you have in those of the past, to promote in every possible way its welfare, thereby enlarging its sphere of usefulness, that still greater success may be your portion.

The Treasurer then submitted his annual report as follows;

REPORT OF THE TREASURER.

George E. Batchelder, in Account With the New England Water Works Association.

RECEIPTS.

1897.	Balance on hand as per last report:		
	People's Savings Bank	$ 1,116.40	
	Safe Deposit and Trust Co.	1,377.48	
	City National Bank	227.86	
			$ 2,721.74
Sept. 24.	Received from J. C. Whitney, Secretary	$ 750.00	
" 27.	" " " "	350.00	
1898.			
Feb. 10.	" " " "	700.00	
Mar. 14.	" " " "	250.00	
May 18.	" " " "	300.00	
June 13.	" " " "	550.00	
			$ 2,900.00
Aug. 1.	People's Savings Bank, interest	$ 44.64	
Sept. 1.	Safe Deposit and Trust Co., interest	51.99	
" 1.	City National Bank, interest	5.50	
			$ 102.13
			$5,723.87

EXPENDITURES.

1897.		
Aug. 26.	Newton Journal, printing programmes, circulars, etc.	$ 54.50
" 31.	W. T. Almy, badges	13.20
Sept. 13.	Thomas P. Taylor, illustrating papers, and expenses at Newport	18.72
" 16.	Bacon & Burpee, report of proceedings and expenses at Newport	70 00
" 27.	Electro-Light-Engraving Co., eng. diagrams	5.19
Oct. 15.	Boston Society of Civil Engineers, rent to October 15, 1897	150.00
Nov. 15.	The Day Publishing Co., printing Sept. Journal.	255.80
" 22.	Electro-Light Engraving Co., engraving plans	13.91
" 24.	W. H. Richards, salary to Sept. 1, 1897, postage, telegrams, telephone, etc	89.15
" 27.	J. C. Whitney, salary to Sept. 1, 1897	125.00
Dec. 1.	" " " Dec. 1, "	125.00
" 11.	Electro-Light Engraving Co., engraving charts	11.83
" 24.	Newton Journal, printing letter heads, envelopes and circulars	19.28
1898.		
Jan. 1.	The Day Publishing Co., printing Dec. Journal.	202.65
" 15.	W. H. Richards, salary to Dec. 1, 1897, express, postage, traveling expenses	95.21
	Amount carried forward	$1,249.44

	Amount brought forward	$1,249.44	
Jan. 15.	Boston Society of Civil Engineers, rent to Jan. 15, 1898	100.00	
" 21.	Electro-Light Engraving Co., eng. diagrams	4.03	
" 29.	" " " " " "	1.00	
Feb. 5.	J. C. Whitney, fares June meeting, telegrams, telephones, etc. as per vouchers	146.31	
" 12.	W. E. Hassam, expenses to Feb. meeting	2.25	
" 23.	Chatterton-Warburton, floral pillow	10.00	
Mar. 1.	Oliver Ditson Co, music at Feb. meeting	8.00	
" 1.	The Day Publishing Co., printing March Journal	145.55	
" 2.	Newton Journal, printing wrappers and circulars	21.50	
" 10.	Bacon & Burpee, report of winter meeting	72.50	
" 26.	W. H. Richards, salary to March 1, 1898, traveling expenses, postage, etc	92.58	
May 31.	Newton Journal, printing postals, circulars, etc.	8.00	
June 1.	Electro-Light Engraving Co., merchandise	13.94	
" 1.	J. S. Roberts & Son, express	.85	
" 4.	J. C. Whitney, salary to June 1, 1898.	250.00	
" 4.	" " postage, telegrams, express, as per vouchers	55.13	
" 17.	W. H. Richards, salary to June 1, 1898, express, telegrams, postage, etc	91.84	
" 17.	The Day Publishing Co., printing June Journal	364.03	
July 15.	Boston Society of Civil Engineers, rent to June 1, 1898	150.00	
			$ 2,786.95

BALANCE ON HAND.

Aug. 1.	People's Savings Bank	$ 1,161.04	
Sept. 1.	Safe Deposit and Trust Co.	1,429.47	
" 1.	City National Bank	346.41	
	Total Cash on Hand		$ 2,936.92
			$ 5,723.87

Respectfully submitted,

GEORGE E. BATCHELDER, *Treasurer.*

REPORT OF THE FINANCE COMMITTEE.

In compliance with the by-laws of this Association, your committee has examined the books of the Treasurer and found the same to be correct. Respectfully submitted,

A. R. HATHAWAY,
A. W. F. BROWN, } *Finance Committee.*

September 13, 1898.

On motion of Mr. Hastings of Concord, N. H., the report of the Treasurer was received and placed on file.

On motion the report of the Finance Committee was received and placed on file.

The Secretary submitted the following report, which was received and placed on file:

REPORT OF THE SECRETARY.

Summary of Statistics Relative to Membership for Year Ending June 1, '98.

ACTIVE MEMBERS.			
June 1, 1897, total active membership		464	
Withdrawals during the year		14	
		450	
INITIATIONS:			
September, 1897	20		
December, 1897	7		
January, 1898	2		
February, 1898	2		
March, 1898	7		
		38	
June 1, 1898, total active membership			488
HONORARY MEMBERS.			
June 1, 1897, total honorary membership		5	
June 1, 1898, total honorary membership		—	5
ASSOCIATE MEMBERS.			
June 1, 1897, total associate membership		80	
Withdrawals during the year		8	
		72	
INITIATIONS:			
September, 1897		5	
June 1, 1898, total associate membership			77
June 1, 1898, total membership			570

A gain for the year of 21.

Summary of Receipts for the Year Ending June 1, 1898.

	Dr.
Received for annual dues	$1,485.00
" advertisements	1,168.00
" initiations	120.00
" Journals	122.00
" miscellaneous	5.00
	$2,900.00

Cr.

Sept. 24, 1897.	Paid Geo. E. Batchelder, Treasurer...	$	750.00
Dec. 23, 1897.	" "		350.00
Feb. 10, 1898.	" "		700.00
Mch. 12, 1898.	" "		250.00
May 17, 1898.	" "		300.00
June 12, 1898.	" "		550.00
		$	2,900.00

The President announced that since the close of the year, in June, the Association had lost by death another member, Mr. Wilbur D. Fiske of Boston, who was an active member of the Association and an active participant in its meetings.

AFTERNOON SESSION.

At the afternoon session Frederick S. Hollis, Biologist, Metropolitan Water Board, Boston, read a paper entitled: "Method for Determination of Color and the Relations of the Color to the Character of the Water."

The discussion was participated in by Messrs. Whitney, Haskell, Fuller, Chase and Bancroft.

EVENING SESSION.

At the evening session William R. Hill, Chief Engineer and Superintendent, Syracuse, N. Y., read a paper entitled: "Some Things that Should be Done in Constructing a Distributing System of Water Works."

The paper was discussed by Messrs. Chase, Whitney, Hawley, Fuller, Haskell, Crandall of Burlington, Walker, Hyde, Thomas of Hingham, Coffin and Richards.

The President presented to the Association Mr. John O. Ayres, saying: As we visit different New England cities, we meet with many peculiar features of water works construction and management. One of the most peculiar, and one which I think will be appreciated by the superintendents present, is met with here in the city of Portsmouth, in the circumstance that for nearly one hundred years the works have had but three superintendents. I have the pleasure of presenting to you Mr. John O. Ayers, who has been connected with these works for the past thirty years. (Applause.)

REMARKS OF SUPERINTENDENT AYRES.

Mr. President, and Gentlemen of the Association:

I have been requested by your Secretary to give you a little informal talk about the Portsmouth water works. The works were chartered in 1797, and were built in 1798. The construction would be considered rather crude today, but still it answered very well for the purpose. They used what they called pump-logs cut in lengths of from 14 to 16 feet, with a bore 5 inches in diameter, and hooped at each end. To connect them they used oak tubes, which were turned to taper at each end and were then inserted in the logs and the logs driven together. The cost of the first main laid in 1798 was approximately $7,000. The Company had at first 127 water-takers and received from them in 1798 $638. In 1800, the number of water-takers had increased only 15, making 142 water-takers, paying $710. In 1805, they had increased to 245, paying $1,325; in 1810, they had increased only 20, to 265, and increased the revenue $50, paying $1,375; in 1820, only 20 more had been added, there being 285 takers, paying $1,400; in 1830, they had increased to 340, paying $2,000; in 1840, there had been an increase of takers up to 459, paying $2,800; in 1850, they had increased to 700, paying $5,000; in 1860, they had increased 400 to 1,100, paying $6,500, an increase of $1,500 in the last ten years; in 1870 they had increased to 1,400 takers, paying $18,000; in 1880, to 1,700 takers, paying $19,000; and in 1890, the last year of the existence of the old corporation under the name of the "Proprietors of the Portsmouth Aqueduct," the number of takers had increased to 1,900 and the water rates amounted to $23,000.

In 1808–9, some ten years after the first construction, a second main of the same character, old pump logs, was laid from the same source of supply, which was springs not over 4 feet deep, and from which the water has flowed ever since and is now flowing to our pumps from the same spot at the rate of three or four hundred thousand gallons a day. Those springs supplied the city directly, without any expense of consequence, until 1850, when a distributing reservoir was built holding 500,000 gallons.

Perhaps it will be well enough to say here, before I go any further, that the demand for water in those days was simply in the

cellars of the houses. A good many of the service pipes were wood logs of an inch and a half bore. Lead was costly, probably, I think it was imported from England, and consequently wood services were used.

In 1850 this distributing reservoir was built. The increase in the revenue from 1840 to 1850 was owing largely to the establishment of the breweries, some of the takers using at least 250,000 gallons a day, and the small works were taxed sometimes pretty severely to supply the demand and to keep up what little head there was, for the pressure was light.

My father was superintendent of the work for nearly fifty years, and I grew up as a boy with the works and have been acquainted with them from the time I was big enough to know anything, being around and about them all the time, and particularly in the summer when any work was done I was very apt to be on hand and to see what was going on.

In 1890, the works were sold to the City of Portsmouth, to be delivered on the 1st of January, 1891. Commissioners were appointed under the bill granting the city the right to purchase, the works were taken and the city proceeded to construct a modern system, using, however, the same sources of supply that the old company had acquired and had used. Between 1860 and 1890 the company had added three sources of supply, one some miles to the north of the original source, one about three-quarters of a mile to the south, and another about half a mile to the east, each having a different elevation. In 1875, in the locality at the north we put down two 8-inch driven wells that have proved very successful. One is 70 feet deep and one 60 feet deep. The two are within 250 feet of each other, and from each of them I think there could be easily pumped a million gallons a day, any day in the year. We simply use them now in extreme drouth in summer. Some years we do not have to use them at all. We have an auxiliary pump located there. The city, after buying the works, built a pumping station and concentrated all these different supplies of water at the lowest point, and put in a 2,000,000 Deane pump, and an auxiliary 1,000,000 Deane pump. Last year they changed and put in a 3,000,000 gallon Worthington. The demand for water this summer has been very large, although some of our largest takers are partially supplying themselves with water from their own works. The largest

day's pumpage was 1,800,000 gallons, and I think we have averaged 1,350,000 gallons a day since the first day of June.

Perhaps you may be interested to know of some of the troubles we experienced with the old pump logs. As late as in the sixties one of the mains was not furnishing nearly as much water as the adjoining one. After considerable search we discovered that a tree some 30 feet away had thrown out its roots and the fibers had grown through the thinnest part of the log near the point, and had filled it, for 5 feet in length, nearly solid full, stopping it up almost completely. The durability of the old logs under the pressure we had was somewhat astonishing, the last three of those laid in 1798 being taken up in the seventies. Instead of being 5-inch bore they were 8, with the knots protruding in all directions, the knots not having worn away as fast as the soft wood, and being as fine and smooth as polished mahogany. If any of you have questions to ask which I can answer I shall be pleased to do so.

MR. HOLDEN. What pressure was on the old logs?

MR. AYRES. Until 1860, there was about 24 pounds pressure. Logs, as we all know, would be good for nothing except under light pressure. We used some Wyckoff patent pipe under 35 pounds pressure from the springs we added in 1875, and it answered very well, except through a clay swamp, where we found it almost worthless, as the bands were eaten off very quickly. But after 15 years of use we could see no deterioration in the pipe which was laid through gravel.

MR. FULLER. How were the joints for the service pipe made?

MR. AYERS. The joints for the service pipes, after we commenced to use lead, were simply bored, and the lead pipe pushed in and wedged with dry, clear pine.

MR. FULLER. A short piece of lead pipe connecting the main with the wooden service pipe?

Mr. AYERS. Yes, when we used wooden services. We have used all kinds of services, and perhaps some kinds that some of you gentlemen have never seen. At one time for people who could afford it and were somewhat afraid of lead and wanted something different, we put in what was called glass-lined pipe, manufactured by a party in Boston. This was a cast-iron pipe an inch and a half in diameter, through which was run a glass tube about half an inch

thick, and between that and the iron pipe it was filled in with calcine. Then, later, parties wanting a glass pipe purchased what they called a glass enamelled pipe made in England, a ¾-inch pipe costing 57 cents a foot, and 1-inch pipe costing some 70 cents, I think. That was simply an enamel of glass inside and out on a wrought-iron pipe. The first pipe I spoke of, the cast-iron lined with glass, cost 50 cents a foot in those days. Some of the older people, however, would never have anything but wood.

MR. BISBEE. Was this wrought-iron pipe threaded, did it have a thread on, or was it put together with lead joints?

MR. AYRES. The first I named was put together with lead joints. It was a perfect pipe, as far as carrying the water was concerned, if they kept the frost out of the cellars. I never knew but one to freeze, and that was in one of our best houses. The weather was very cold, below zero, and the parties left the big cellar door some four feet from the pipe open over night, and in the morning they had no water. Complaint was made that they couldn't get any water, and that there must be some trouble with the works. The water froze in some 4 or 5 feet of pipe and the glass was shivered in all shapes.

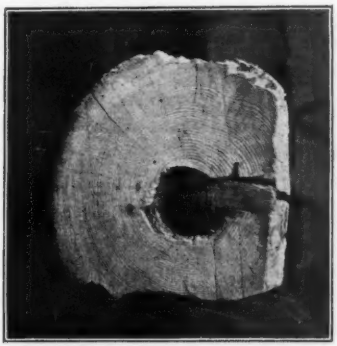
MR. FULLER. I suppose there were no hydrants connected with the old mains?

MR. AYRES. All the fire protection was from reservoirs, which the old company filled for the city free of cost. They never charged the city for water for fire purposes or for school-houses. Perhaps I might say further that there were very few years but what the old company paid a dividend. I should like to show you the old record book of 1798, for I think the handwriting of the old fellow, who has passed on, and some of the entries he made, might interest you.

THE PRESIDENT. Is there any of the old log pipe in existence at the present time?

MR. AYERS. None that I know of. I should be pleased to see any of you in my office before you go back, or all of you who can get in there. (Applause.)

On motion of Mr. Hill the thanks of the Association were extended to Mr. Ayers.



SECTION OF WATER LOG.

This log or wooden water pipe was a part of the Boston Aqueduct laid in 1836, and was taken from under the house of Wendell Phillips in Essex Street. This illustration is from a piece presented to Mr. Henry F. Jenks by the Ashton Valve Co.

THURSDAY, September 15.

The convention met at 10.20.

The Secretary read the following names of applicants for membership, the applications having been approved by the Executive Committee:

RESIDENT-ACTIVE.

P. D. O'Connell, Superintendent, Somersworth, N. H.; A. H. Burse, Superintendent, Pittsfield, Maine.

On motion of Mr. Crandall of Burlington, the Secretary was directed to cast the ballot of the Association for the applicants, which he did, and they were declared elected.

Mr. Stacy moved the appointment by the chair of a committee of five to make nominations of officers for the ensuing year. The motion was adopted and the chair appointed the following as the committee: Messrs. Stacy, Kieran, Codd, Holden and Cook of Woonsocket.

AMENDMENT OF THE CONSTITUTION AS TO PLACE OF MEETING.

THE SECRETARY. There is a report of the Executive Committee of the Association containing a recommendation for an amendment

to the constitution. The amendment suggested is in Section 3 of Article VII, which now reads as follows: "The place for holding the regular meetings of the Association shall be decided by vote of the members, but no regular meeting shall be holden outside the New England States." The amendment recommended is that the clause "but no regular meeting shall be holden outside the New England States" be stricken out.

MR. RICHARDS. I would like to have the Secretary read the section of the constitution which states how an amendment shall be made.

THE SECRETARY. It is Section 3 of Article VIII, which provides: "All propositions for adding to or altering any provisions of the foregoing constitution shall be submitted to the Executive Committee who may bring the matter before the Association; and they shall bring before the Association any proposed amendment having the written endorsement of ten members. A two-thirds affirmative vote of the members present and voting shall be necessary for the adoption of such amendment."

MR. THOMAS of Lowell. I move that the matter lay on the table until our meeting tomorrow forenoon, and meanwhile the members can be notified of it, and we will probably have a better attendance then than we have now.

Mr. Thomas' motion was adopted.

Mr. Robert S. Weston of Brockton, Mass., read a paper entitled, "The Occurrence of Cristatella in the Storage Reservoir at Henderson, North Carolina."

The paper was discussed by Messrs. Haskell, Hollis and Chase.

Mr. Frank L. Fuller of Boston gave a description of the Monson, Mass., water works, after which the convention adjourned till evening.

EVENING SESSION.

Mr. Henry F. Jenks, who had charge of the exhibit of water works appliances, made the following report:

Hayden & Derbey, Mfg. Co., New York., Metropolitan Injectors and Ejectors.

Builders' Iron Foundry, Providence, Service Box, Pamphlets of Venturi Meters and Globe Specials.

Coffin Valve Co., Boston, Fire Hydrant Gates, Check Valves, Sluice and Sewer Gates.

Fred W. Gow, Medford, Improved Apparatus for Testing Meters.

Hersey Mfg. Co., Boston, Meters.
Union Water Meter Co., Worcester, Pressure Regulators and Meters.
H. Mueller Mfg. Co., Decatur, Ill., Tapping Machines, Regulators and Water Works Supplies.
Lead Lined Iron Pipe Co., Wakefield, Lead Lined Iron Pipe and Fittings.
Henry F. Jenks, Pawtucket, Street and Park Drinking Fountains.
A. P. Smith Mfg. Co., Newark, N. J., Sherly Tapping Machine, Lead Pot Fused with Kerosene Oil, and General Water Works Supplies.
Ashcroft Mfg. Co., New York, Steam, Vacuum and Water Pressure Gauges, Indicators and Recording Gauges.
Rensselaer Mfg. Co., Troy, N. Y., Valve, Gates, and Gate Boxes and Corey Fire Hydrants.
Chapman Valve Co., Boston, Valves and Hydrants.
National Meter Co., New York, Meters.
Neptune Meter Co., New York, Meters.
Ross Valve Co., Troy, N. Y., Valves, Water Engines and Filters.
Thompson Meter Co., Brooklyn, N. Y., Meters.
Consolidated Safety Valve Co., New York, Pop Safety Valves and Water Relief Valves.

Dr. Gardner T. Swarts, secretary of the Rhode Island State Board of Health, read a paper entitled: "Man's Imitation of Nature in Purification of Water."

Following the reading of the paper Mr. Robert S. Weston spoke on the subject of the removal of bacteria and suspended matter in river waters by sedimentation, and gave some facts in regard to the proposed filter plant at Louisville. Subjects considered in the paper were also discussed by Mr. Clark and Mr. Thomas of Hingham.

Mr. George Bowers, city engineer of Lowell, Mass., next read a paper in which he gave the results of tube well experiments in Lowell.

FRIDAY, September 16.

Robert W. Taber, member of the water board of New Bedford, and Washington Paulison, superintendent water company Passaic, New Jersey, were elected active members of the Association.

Mr. John C. Haskell of Lynn, Mass., read a paper on "Surface Water Supplies."

The paper was discussed by Messrs. Clark, Richards and Fels.

A paper, written by Edmund B. Weston, consulting engineer, Providence, R. I., describing the separate high pressure fire service in that city, was read by Mr. French.

A communication was received from Mr. F. A. W. Davis, vice-president and treasurer of the Indianapolis Water Company, enclosing a quotation from the report of the duty test of the Company's new engine, made by Prof. Goss, of Purdue University.

CONSTITUTION AMENDED

The report of the Executive Committee recommending an amendment to the constitution by striking out the clause in section three of article seven, "but no regular meeting shall be holden outside the New England States," was taken from the table.

Mr. Stacy moved that the recommendation be adopted and that the constitution be so amended.

In answer to a question by Mr. Thomas of Hingham as to what per cent of the members live in the New England States, the Secretary said about 80 per cent.

MR. STACY. I am in favor of this amendment, for I think this Association is competent to determine for itself where it wants to hold its meetings. I think it is unnecessary that we should have a prohibitory law in the New England Water Works Association, and if we want to visit California, or the Rocky Mountains, or Chelsea, we have intelligence enough to vote as to where we want to go, and the majority will rule here as in all other organizations.

The motion was adopted.

MR. STACY. I now have a pleasant duty to perform, which has been entrusted to my unworthy care by a gentleman who is himself too modest to state the generous and cordial invitation which he wishes to extend to this Association; and it becomes in order now, since this motion has been adopted by the Association and we are at liberty to hold our meetings where we see fit. I have been requested by Mr. Hill to invite you to hold your next annual meeting in Syracuse. It has been some time since we have had an invitation to meet in any particular place, and it seems to me that an invitation of this kind should have very serious consideration by the members. From the knowledge we have of what the citizens of Syracuse, backing up Mr. Hill, did almost on the spur of the moment for another association which met a few miles from there, we are promised a reception by the citizens, such as almost makes us blush, modest as we are. If we seriously contemplate any excursion of that kind,

we should have due warning so we can have plenty of training to get ready for it. This invitation comes to us spontaneously, a great, generous invitation to visit Syracuse, with a guarantee that we will be royally entertained, a guarantee which is backed up by the experience of others who have been there, and an invitation given not only by one little body of men, but by the leading citizens of the place, who take an honest pride in the growth of the city and who want the whole world to come and see what they have done. They claim, as we all claim, to have the best water works in the country—I wouldn't give a cent for a man who didn't claim that—and they want us to see it. We know if we were going anywhere near Syracuse, from what we have seen in the papers and from the descriptions we have read by prominent engineers of what has been done there, we would all make an effort to visit the city, being sure of learning something there which would be of advantage to us.

This Association has never yet been out of New England. When sometimes a proposition has been made to go more than 50 miles from Boston, we have been scared most to death. Some of us were afraid when we decided to go to Burlington that we wouldn't have any sort of an attendance there, but we found we did have a good attendance, and we had a splendid time, and I think if we had even gone clear across the line we would have gone in good numbers. The American Association, who are our rivals in one sense in promulgating knowledge on water works matters to the people, go all over the United States, yet we have just been paddling about around in New England all the time, while beating them in almost everything else. Now it seems to me if we go to Syracuse, we will be near Niagara Falls, and near the Thousand Islands, and we could see a good deal more even than we could in Lynn, and we saw a good deal in Lynn. (Laughter and applause.) I think a change of scene will do us good. It won't do us any harm to get out of New England and knock a little rust off us by rubbing up against some other people.

I am glad this invitation has come at this time so that we can thoroughly consider it. We are not obliged to settle it today, and I hope to see, with a membership of over 500 in the Association, great enthusiasm in carrying out what is for the best interests of the Association. And I think, if we can work up properly this trip to

Syracuse, we will have one of the largest and most interesting meetings we have ever had, with lots of visitors, and lots of men who are interested in exhibiting to us what is new in the way of water works supplies, and in telling us what is going on. We have a pretty little exhibit here, but it is only a small sample of what we ought to have. There is one thing I want to impress upon you, and that is the heartiness of this invitation, the ocean of generosity which is behind it, and the anxiety of the citizens of Syracuse to back it up and to show us what they have got and what nice people they are.

THE PRESIDENT. The invitation is certainly very cordial and generous, and it will be referred to the Executive Committee to be reported upon at the first winter meeting of the Association.

ELECTION OF OFFICERS.

Mr. Stacy, chairman of the committee appointed to nominate officers for the ensuing year, presented the following report:

PRESIDENT.

F. F. FORBES, Superintendent, Brookline, Mass.

VICE-PRESIDENTS.

MELVILLE A. SINCLAIR, Superintendent, Bangor, Me.; CHARLES K. WALKER, Superintendent, Manchester, N. H.; F. H. CRANDALL, Superintendent, Burlington, Vt.; BYRON I. COOK, Superintendent, Woonsocket, R. I.; ROBERT J. THOMAS, Superintendent, Lowell, Mass.; R. S. BARTLETT, Superintendent, Norwich, Conn.

SECRETARY.

JOHN C. WHITNEY, Commissioner, Newton, Mass.

TREASURER.

GEORGE E. BATCHELDER, Water Registrar, Worcester, Mass.

SENIOR EDITOR.

JOSEPH E. BEALS, Superintendent, Middleboro, Mass.

JUNIOR EDITOR.

WALTER H. RICHARDS, Superintendent, New London, Conn.

EXECUTIVE COMMITTEE.

PATRICK KIERAN, Superintendent, Fall River, Mass.
JOHN C. HASKELL, Superintendent, Lynn, Mass.
GEORGE A. STACY, Superintendent, Marlborough, Mass.

FINANCE COMMITTEE.

WILLIAM F. CODD, Superintendent, Nantucket, Mass.
ARTHUR W. F. BROWN, Registrar, Fitchburg, Mass.
HORACE KINGMAN, Superintendent, Brockton, Mass.

On motion of Mr. Chace, the report of the nominating committee was accepted, and the Secretary of the Association was directed to cast one ballot in favor of the nominees, which he did, and they were declared elected.

On motion of Mr. Richards, the thanks of the Association were tendered to the retiring President, Mr. Kent, and to the Secretary.

Adjourned.

Attendance at 1898 Convention of the New England Water Works Association held at Portsmouth, N. H., September 14th, 15th and 16th.

ACTIVE MEMBERS.

Willard Kent, Narragansett Pier, R. I.; R. J. Thomas, Lowell, Mass.; Edw. L. Peene, Yonkers, N. Y.; Lewis M. Bancroft, Reading, Mass.; Fred W. Gow, Medford, Mass.; Albert S. Glover, Boston, Mass.; A. W. F. Brown, Fitchburg, Mass.; J. C. Whitney, Newton, Mass.; Charles S. Warde, Staten Island, N. Y.; George E. Batchelder, Worcester, Mass.; Joseph E. Beals, Middleboro, Mass.; Wm. F. Codd, Nantucket, Mass.; A. H. Salisbury, Lawrence, Mass.; F. E. Bisbee, Auburn, Me.; Chas. H. Baldwin, Boston, Mass.; W. G. Zick, New York, N. Y.; J. C. Sullivan, Holyoke, Mass.; C. D. Colson, Holyoke, Mass.; J. L. Tighe, Holyoke, Mass.; James Burnie, Biddeford, Me.; F. S. Hollis, Boston, Mass.; G. W. Harrington, Wakefield, Mass.; F. L. Northrop, Boston, Mass.; W. C. Hawley, Atlantic City, N. J.; P. D. O'Connell, Somersworth, N. H.; Daniel B. McCarthy, Waterford, N. Y.; W. R. Hill, Syracuse, N. Y.; V. C. Hastings, Concord, N. H.; James A. Huntington, Haverhill, Mass.; J. Waldo Smith, Paterson, N. J.; W. Paulison, Passaic, N. J.; Frank A. Andrews, Nashua, N. H.; J. F. Gleason, Quincy, Mass.; W. W. Ewell, Quincy, Mass.; F. H. Crandall, Burlington, Vt.; Patrick Kieran, Fall River, Mass.; D. N. Tower, Cohasset, Mass.; Wm. H. Thomas, Hingham, Mass.; Freeman C. Coffin, Boston, Mass.; George F. Chace, Taunton, Mass.; Henry A. Cook, Salem, Mass.; George K. Crandall, New London, Conn., L. E. Daboll, New London, Conn.; Byron I. Cook, Woonsocket, R. I.; W. H. Richards, New London, Conn.; Thomas C. Gleason, Ware, Mass.; X. H. Goodnough, Boston, Mass.; H. N. Hyde, Newton, Mass.; F L. Fuller, Wellesley, Mass.; George Bowers, Lowell, Mass.; Robert S. Weston, Brockton, Mass.; M. A. Sinclair, Bangor, Me.; H. T. Sparks, Bangor, Me.; George A. Stacy, Marlboro, Mass.; James F. Bigelow, Marlboro, Mass.; George E. Crowell, Brattleboro, Vt.; H. G. Holden, Nashua, N. H.; A. H. Burse, Pittsfield, Me.; D. H. Gilderson, Haverhill, Mass.; George E. Winslow, Waltham, Mass.; J. W. Crawford, Lowell, Mass.; John C. Haskell, Lynn, Mass.; Frank E. Merrill, Somerville, Mass.; C. E. Chandler, Norwich, Conn.; H. W. Clark, Boston, Mass.; E. V. French, Boston, Mass.; Daniel Russell, Everett, Mass.; Louis E. Hawes, Boston, Mass.

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HONORARY MEMBERS.

"Engineering News," by Samuel B. Read and M. N. Baker; "Engineering Record," by Henry C. Meyer and G. H. Partridge; "Fire and Water," by F. W. Sheppard.

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ASSOCIATE MEMBERS.

Ashcroft Mfg. Co., by Frank Andrews.
Builders' Iron Foundry, by S. C. Clifford.
Chapman Valve Co., by E. L. Ross.
Deane Steam Pump Co., by Charles P. Deane and Allen M. Pierce.
Hersey Mfg. Co., by James A. Tilden, F. B. Smith, A. A. Blossom.
Jenks, Henry F., Pawtucket, R. I.
Ludlow Valve Mfg. Co., by H. F. Gould.
Lead Lined Pipe Co., by T. E. Dwyer.
Mueller Mfg. Co., by F. B. Mueller, M. G. Millikin.
National Meter Co., by John C. Kelley, W. P. Oliver, J. G. Lufkin.
Neptune Meter Co., by H. H. Kinsey.
Rensselaer Mfg. Co., by Fred S. Bates.
Ross Valve Co., by William Ross.
Smith A. P. Mfg. Co., by W. H. Van Winkle.
Thomson Meter Co., by Henry Folger, S. D. Higley.
Worthington, H. R., by J. M. Betton.

GUESTS.

Mrs. Lewis M. Bancroft, Reading, Mass.; Miss Mabel E. Bancroft, Reading, Mass.; Mrs. E. L. Ross, Indian Orchard, Mass.; Mrs. W. H. Van Winkle, Newark, N. J.; Mrs. Joseph E. Beals, Middleboro, Mass.; Mrs. J. P. Bacon, Cambridge, Mass.; Mrs. James A. Tilden, Boston, Mass.; Miss B. F. Whitaker, Boston, Mass.; Mrs. G. W. Harrington, Wakefield, Mass.; Mrs. J. F. Gleason, Quincy, Mass.; Mrs. W. W. Ewell, Quincy, Mass.; Mrs. George K. Crandall, New London, Conn.; Mrs. L. E. Daboll, New London, Conn.; Mrs. George Bowers, Lowell, Mass.; Mrs. H. G. Holden, Nashua, N. H.; Mrs. William H. Thomas, Hingham, Mass.; Mrs. D. N. Tower, Cohasset, Mass.; Mrs. George F. Chace, Taunton, Mass.; Mrs. C. A. Kent, Narragansett Pier, R. I.; James P. Bacon, Cambridge, Mass.; W. H. Lawrence, Newburyport, Mass.; Joseph W. Milne, Fall River, Mass.; Julian P. Wood, Marlboro, Mass.; William E. Hill, Salem, Mass.; C. H. Danforth, Salem, Mass.; Edward E. Brown, Salem, Mass.; F. L. Weaver, Lowell, Mass.; August Fels, Lowell, Mass.; M. J. Dowd, Lowell, Mass.; S. B. Palmer, Norwich, Conn.

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